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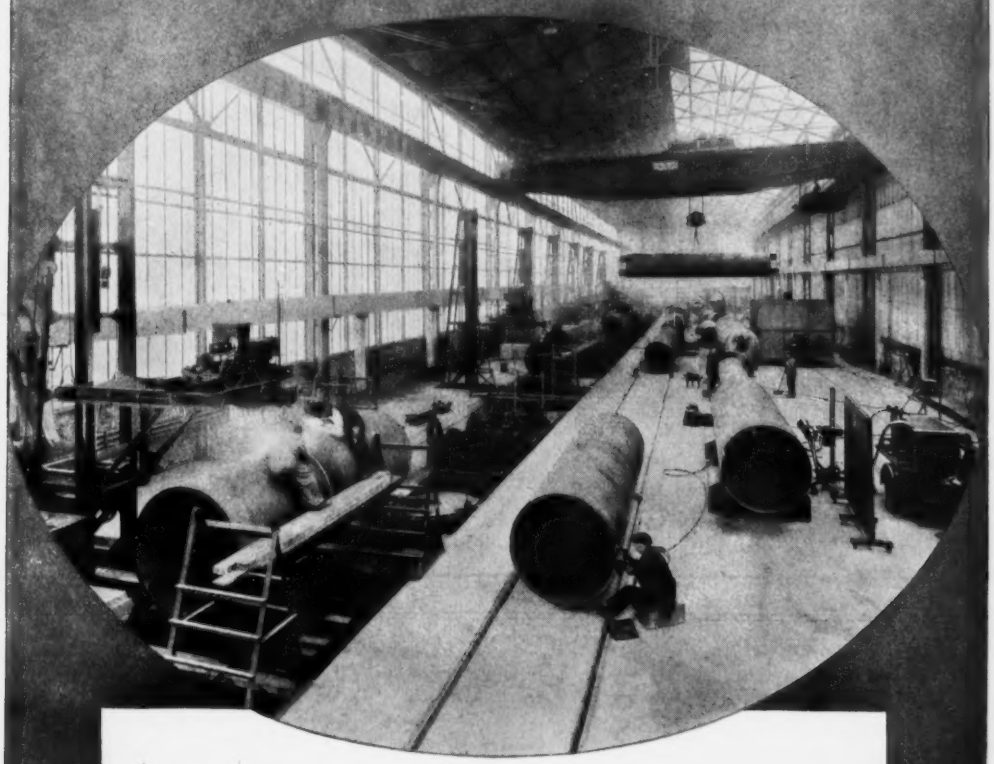

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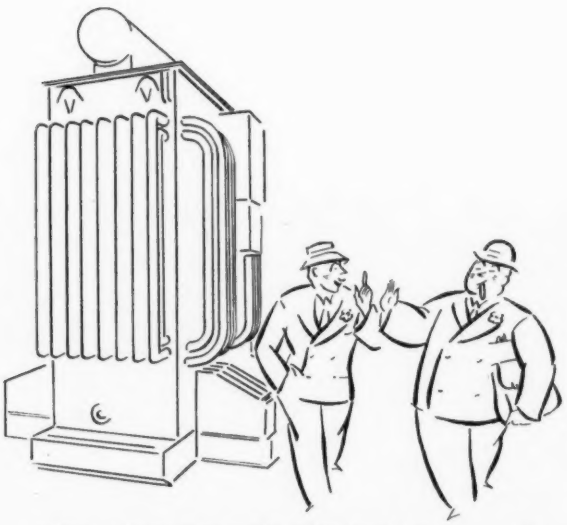

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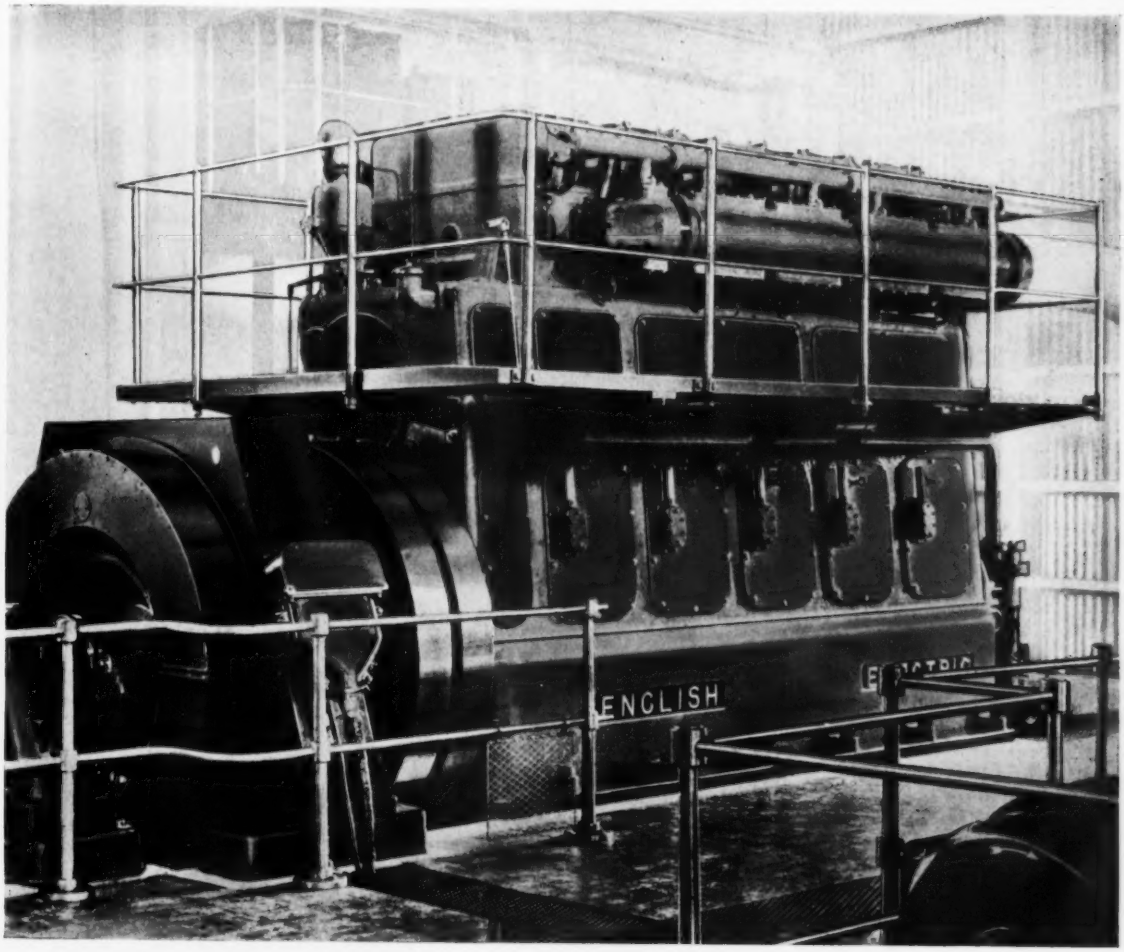

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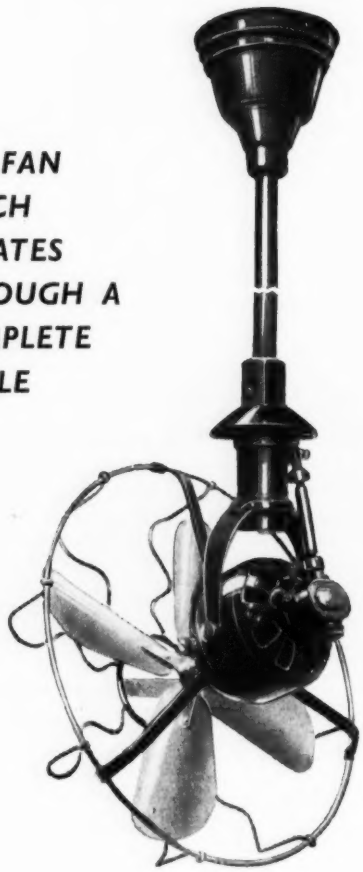

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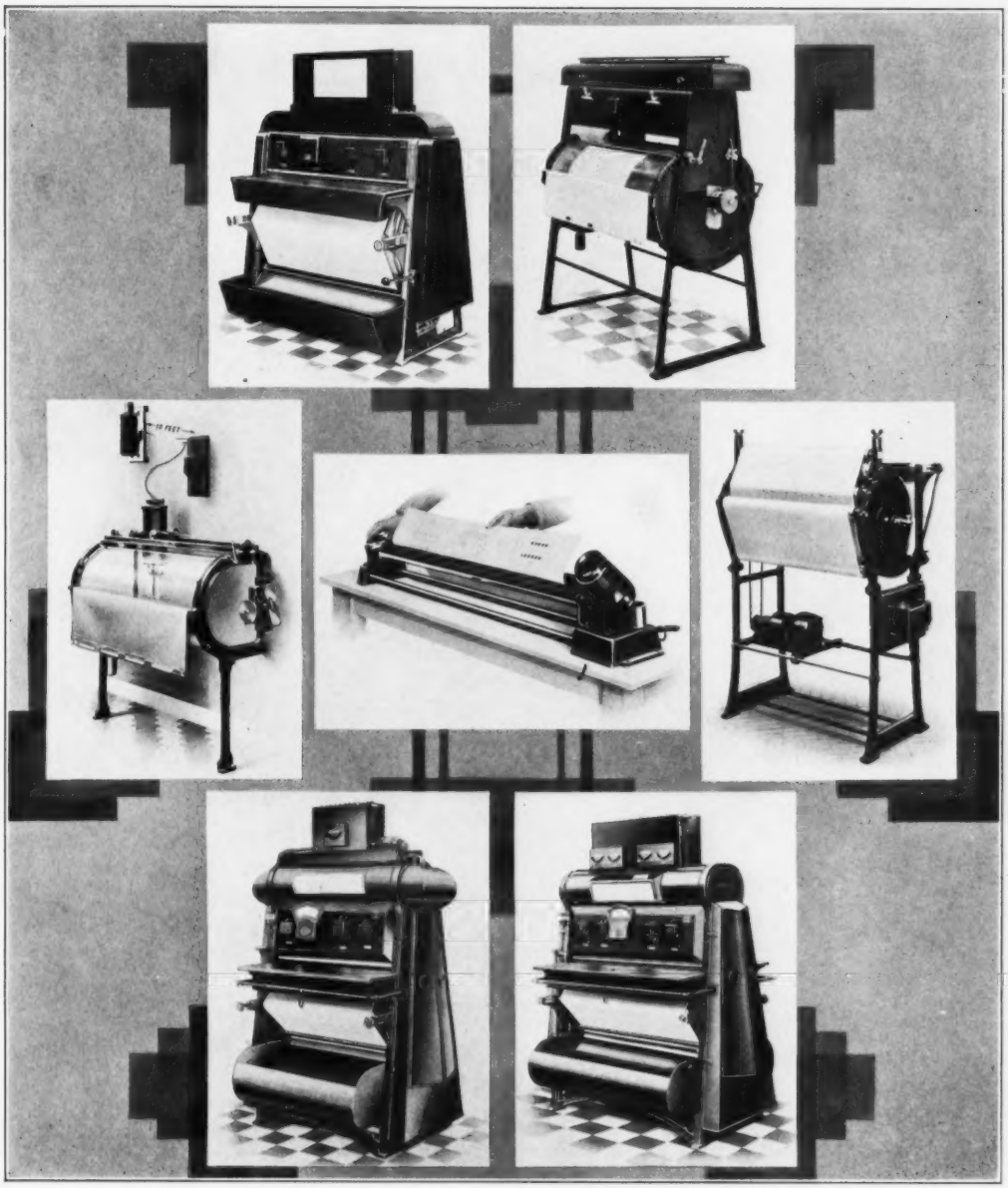

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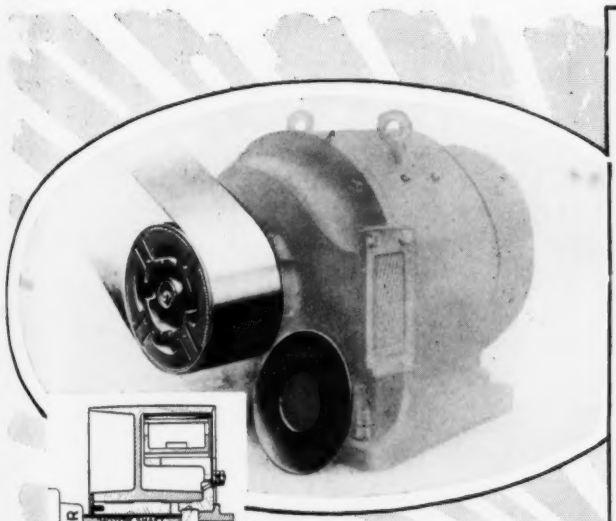

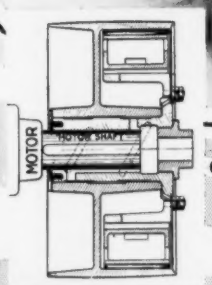

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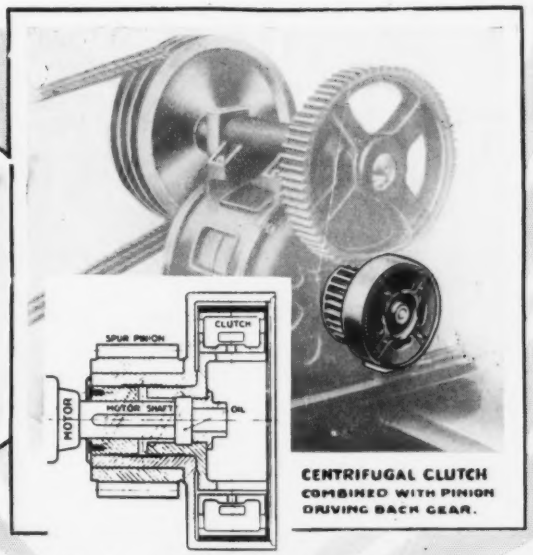

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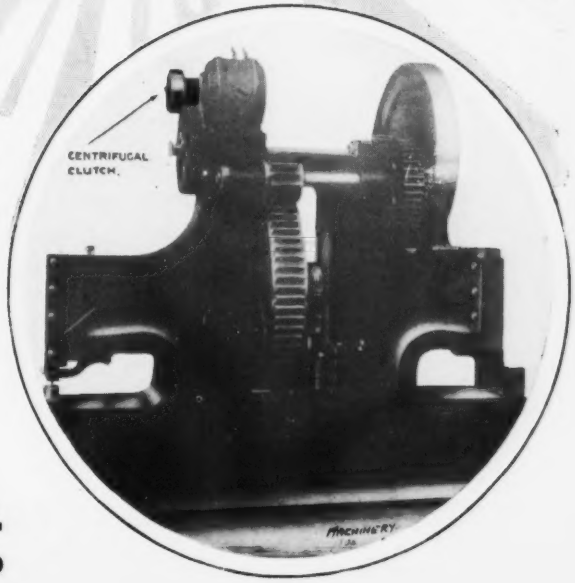

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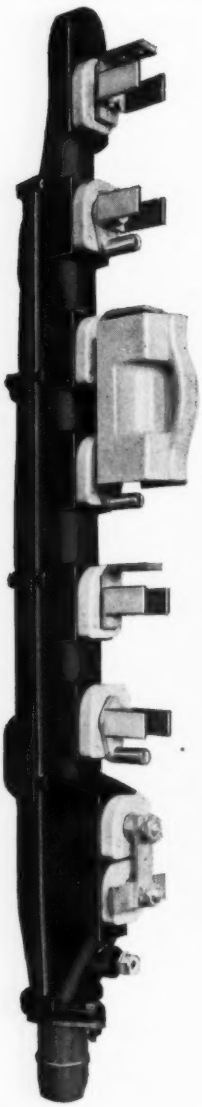

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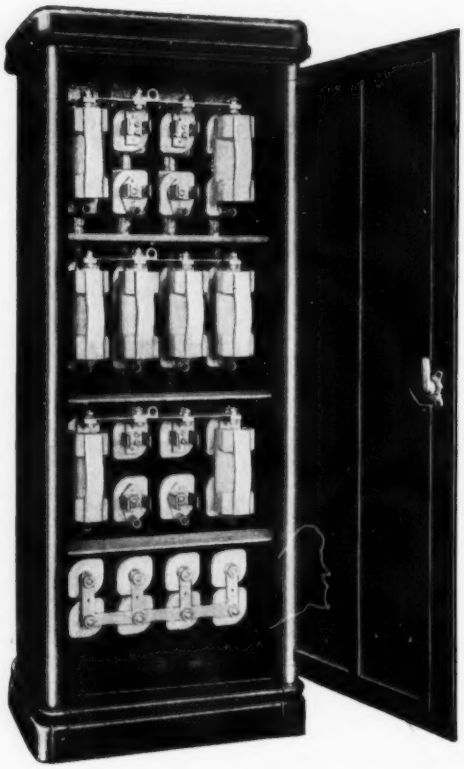

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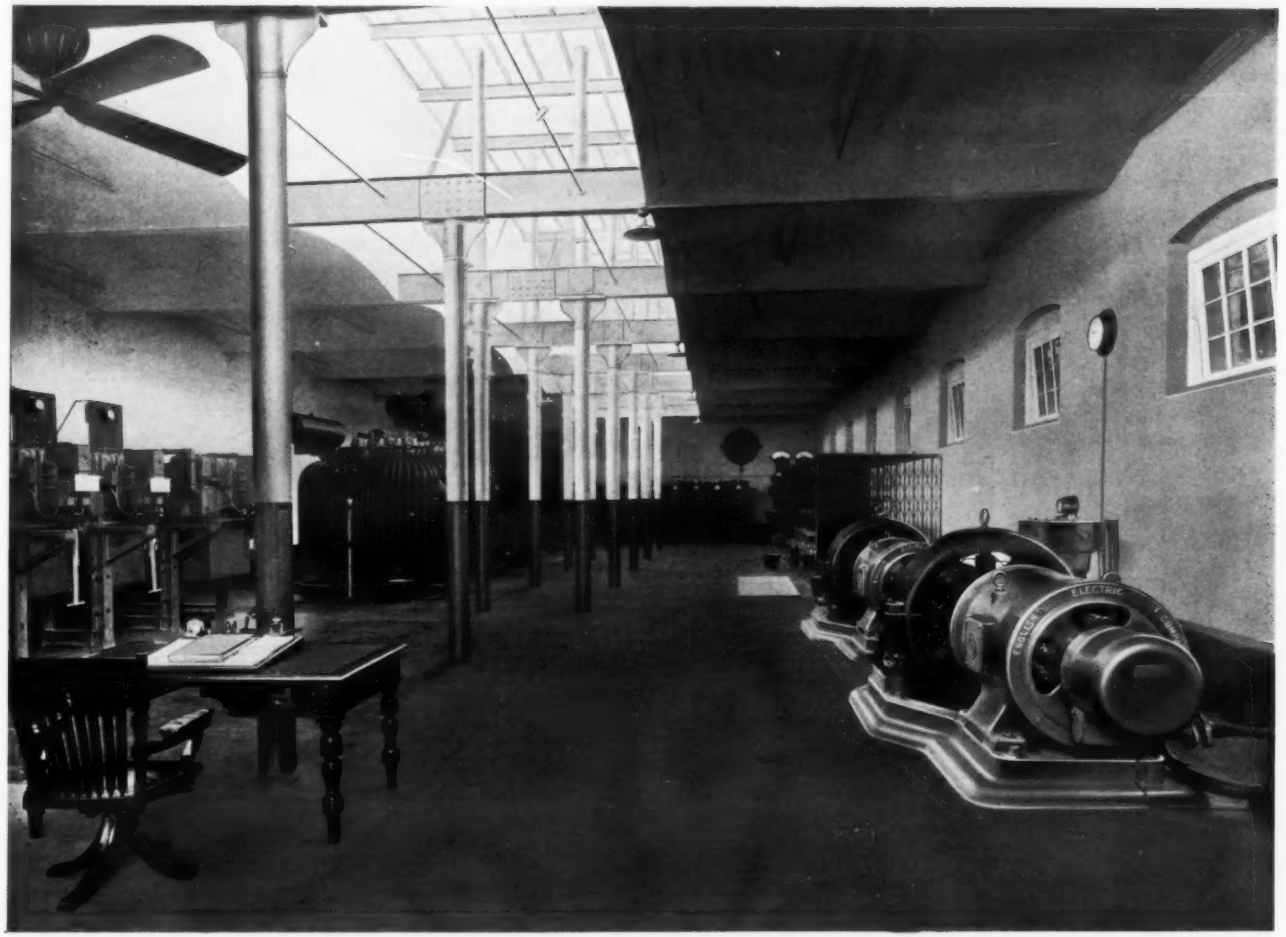

General view of Substation in the Khardah Jute Mills showing part of the 22,000 volt Switchgear, two 1,000 kVA. Transformers, two 5,000 kVA. Transformers, high tension and low tension switchboards and 75 kW. motor generator sets driven by Kosfi Motors.

The English Electric Journal

Vol. VIII. No. 5 MARCH, 1937 One Shilling.

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All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, THE ENGLISH ELECTRIC COMPANY LIMITED, STAFFORD.

EDITORIAL.

Our frontispiece shows the substation of the Khardah Jute Mill, Calcutta, which is believed to be the largest mill under one roof on the River Hooghly. The complete conversion to electric drive was carried out by our Company, and in the first article in this issue Mr. F. Watson describes the electrification of the mill.

Electric drives for the mill machinery were chosen because the existing steam power plant was reaching the limit of its economical life, and owing to the low prices prevailing for the finished product of the mill it was essential to reduce power costs as far as possible. In order to obtain the full benefits of the attractive power rates offered by the Calcutta Electric Supply Corporation, the installation includes a number of the Company's asynchronous-synchronous motors, and Kosfi motors, for power factor correction.

Electric plant in Calcutta operates under much more arduous conditions than obtain in this country, shade tem-

peratures of 115°F. and humidity approaching saturation point being quite common. The Company has in the past supplied a large amount of plant to meet such conditions and the fact that "English Electric" motors were chosen is testimony to their design, workmanship and reliability.

In the article following Mr. A. R. Blandford reviews the new standards of performance for high rupturing capacity switchgear, which have been based on extensive test experience with large testing plants. In the past, owing to the lack of adequate test facilities circuit-breakers were rated on empirical formulæ and general field experience, and in many cases were given too high a rupturing capacity rating.

Reference is made to the desirability of an efficient arc control in order to minimise risk of fire and danger to operators, and the Company's de-ion grid is shown to have all the essential features of an efficient and satisfactory device. The author also gives in brief outline a layout of substation switchgear which would enable a power supply to be maintained even if by any chance a fire should occur in the substation.

In the third article Mr. R. M. Charley describes and illustrates some reactors which the Company has supplied for use on a 132 kV. system of the Central Electricity Board. It is pointed out that where the rupturing capacity rating of switchgear built some years ago has been found in the light of recent investigations to be too high, reactors should be installed as a safeguard. Furthermore, the enormous increase in the capacity of generating plant coupled to the Grid has necessitated reactors being connected between sections at selected points, in order to ensure that should a fault occur in any section, the short-circuit current fed into it would not exceed a safe limit for the switchgear.

Finally Mr. Charley gives a description of interesting reactor and transformer installations at Brighton. In this connection we are pleased to advise our readers who will be attending the I.M.E.A. Convention at Brighton (31st May to 4th June) that Mr. W. N. C. Clinch, Engineer and Manager of the Brighton Corporation Electricity Undertaking, has been kind enough to invite delegates and visitors to inspect the reactors at the Southwick Power Station, and the transformers at the North Road distribution centre.

The Electrification of the Khardah Jute Mills.

By F. WATSON, Manager of the English Electric Company's Calcutta Branch.

Introduction.

The world production of jute is virtually a monopoly of Bengal, yet until 50 years ago only a very small quantity of finished cloth was manufactured in India, and that principally on hand looms. During the latter half of the last century, however, rapid development of the natural resources of Bengal took place, and with the growing demand for jute products a large number of mills sprang up around the Bengal capital. To-day more than half of the Indian output of jute is consumed in the local mills.

Bengal possesses a vast network of natural waterways in the jute-growing districts, and this provides an extremely cheap method of transporting the raw material, with the result that practically all the jute mills were built on the banks of the River Hooghly. To-day there are approximately 80 jute mills on the river within a distance of 20 miles north and south of Calcutta.

The majority of these mills are now over 30 years old, but were originally laid out along the lines of the latest practice then ruling in Dundee. They were generally driven by two large horizontal slow-speed steam engines, one for the mill and the other for the factory, the drive to the line shafts taking the form of a series of endless ropes in a rope alleyway which extended the width of the mill and between the mill and the engine room. The steam-raising plant generally consisted of batteries of Lancashire type boilers. It will readily be understood that in the fierce competition which exists at the present day these methods of power generation form a serious obstacle to cheap production. Furthermore, such plant has practically reached the end of its useful life, and not only are the fuel and steam consumption figures very high, but maintenance charges are naturally becoming unduly heavy.

The need for the strictest economy in working in Calcutta is also enforced by other considerations. Until recently practically all the larger mill owners were members of the Jute Manufacturing Association, a body which includes in its aims the avoidance of overproduction and unnecessary competition between manufacturers. During the last few years, however, the number of smaller non-association manufacturers has grown and to some extent the objects of the Association have been defeated. To meet this competition, therefore, various measures were taken by working longer hours, etc. This has had the result of lowering the price of the finished article and has made it still more imperative for the owners of the older factories to seek some alternative and more economical method of driving their mills.

The three principal alternatives are :—

(1) The purchase of modern higher pressure water-tube boilers and steam turbine plant, the latter being provided with suitable reduction gears for coupling to the existing rope drives and with means of passing out from the turbine a sufficient quantity of steam for the process work in the mill.

(2) As above, but with the turbine arranged to drive an alternator which supplies power to motors driving the mill machinery either individually or in groups.

(3) The purchase of electric power from an outside source, together with the installation of motors as in the case of (2).

Khardah Jute Mills.

The Khardah Jute Mills consist of identical mills arranged side by side and form what is

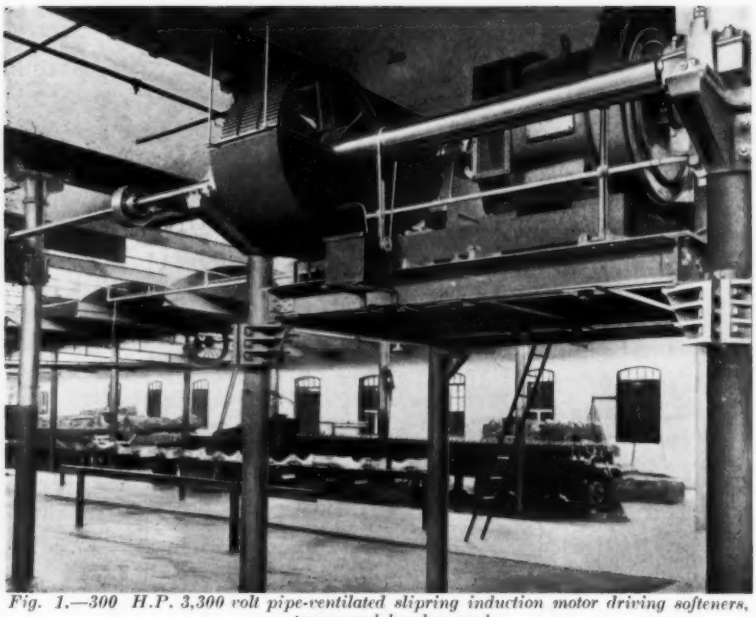


Fig. 1.—300 H.P. 3,300 volt pipe-ventilated slipring induction motor driving softeners, teaser and breaker cards.

believed to be the largest mill under one roof on the river.

Messrs. Anderson, Wright & Co., the Managing Agents of the Khardah Jute Co., gave this problem very serious consideration and found that, like a number of other mills, their power plant, which was originally installed in 1896, was reaching the limit of its economical life, whereas the mill machinery itself was in a much better condition. Both of the first two alternatives previously mentioned would, of course, entail very heavy capital expenditure, and it was eventually decided to take energy from the Calcutta Electric Supply Corporation, who were able to offer extremely attractive rates for the amount of power which the mills would consume.

After considering alternative schemes, the order for the complete conversion of the two mills at Khardah was awarded to the English Electric Company, who have for many years made a close study of the requirements peculiar to the jute manufacturing processes, which in India are considerably aggravated by local conditions.

Of these, mention may be made of the very high temperature and humidity conditions which exist over a large period of the year, and shade temperatures as high as 115 deg. F. and humidity approaching saturation are quite common. This means not only that all the electrical materials must be liberally rated to ensure a reasonable temperature rise, but the ventilation of the machines must be most carefully designed to avoid hot spots, which, in conjunction with the high ambient temperatures, would certainly prove injurious to the insulation. In addition, owing to the high water content of the air, the insulation must be of the highest quality and so treated that it is impervious to moisture.

Another factor which calls for serious consideration is the difficulty in obtaining skilled labour for the operation of the electrical machinery which, therefore, must be foolproof and extremely robust.

Layout of the Mills.

In the Khardah Jute Mills numerous other difficulties existed, but due to the careful consideration of all the details of the scheme in the initial stages, in consultation with the Mill Management, they were satisfactorily overcome.

One of the features of this conversion is the general disposition of the various motors, which are erected on steel platforms in the centre pass of each mill. In a number of mill conversion schemes, the motors are installed in the rope alleyway at the mill ends. The principal advantage of this arrangement is that after the conversion the motor alleyway can be effectively walled in, making it a simple matter to exclude dust and fluff and to utilise ordinary enclosed ventilated motors. The possibility of doing this was

investigated at Khardah, but a number of factors were found which militated this arrangement. By placing the motors in the centre of the mill, however, an important advantage is secured in reducing very considerably the speed variation along the line shaft, which may assume serious proportions in the case of a long line driver at one end. An impression of the platform construction can be obtained from Figs. 1 and 2.

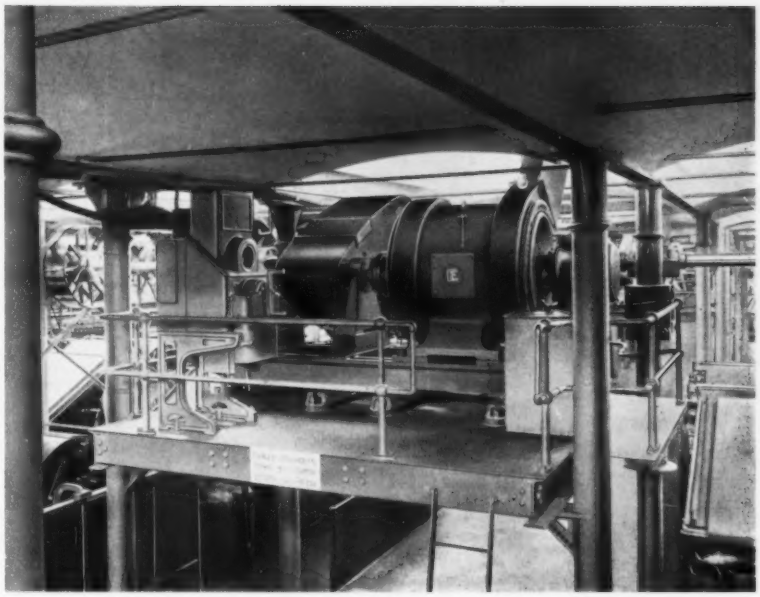


Fig. 2.—300 H.P. 3,300 volt pipe-ventilated slipring induction motor driving breaker, inter-finisher and finisher cards.

It will be noticed that although the roof is somewhat low and sufficient clear working head room had to be provided underneath the platform in the mills pass, there is comfortable head room for working and ample access to the motors and their control gear on the platform. The platforms were fabricated in India and considerable care was taken to prevent vibration. Whenever possible, the existing cast-iron roof columns were utilised, and these were augmented by additional columns with cast-on brackets where necessary.

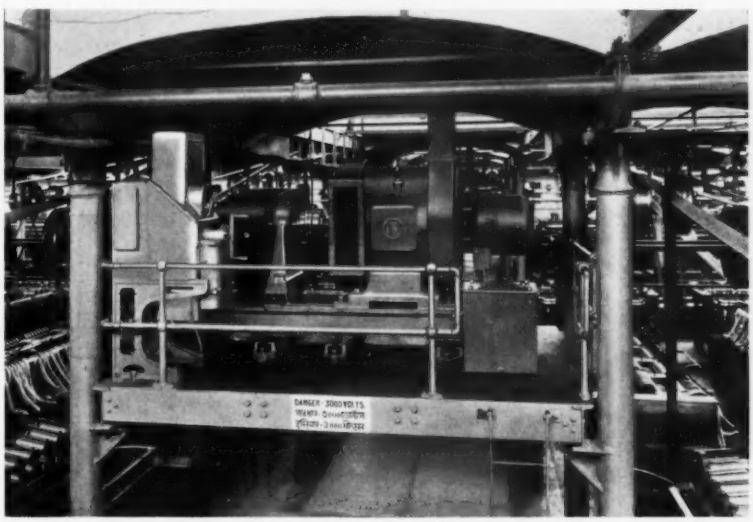


Fig. 3.—200 H.P. 3,300 volt pipe-ventilated slipring induction motor driving overhead line shafting for roving machines.

Owing to the presence of fine jute fibres and dust in the atmosphere, especially at the preparation end of the mill, all the motors, except those in the factory, were arranged for pipe ventilation. The inlet air is drawn through a short length of ducting from the roof, and the intake of this duct is protected by light masonry

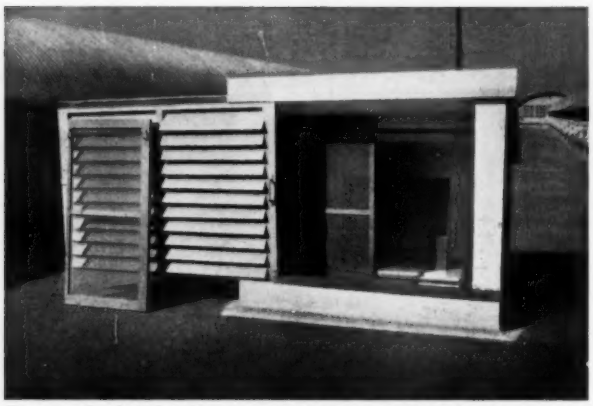


Fig. 4.—Roof shelter for pipe-ventilated motor air intake, showing one gauze dust screen removed and sliding louvre door open.

shelters, which are provided with large area gauze screens to exclude the dust and, as a further protection against the heavy driving monsoon rains, by means of louvres in the sliding door. The ducts are shown in Fig. 3, and Fig. 4 shows the air intake on the roof.

All the main drives in the mill, except the spinning, are carried out by means of Renold inverted tooth chains; the motors run at 750 r.p.m. (syn.), the speed being reduced to either 137 r.p.m. in the mill or 150 r.p.m. in the factory. Generally speaking, 4-feet chain centres have been employed, the drives being totally enclosed and force lubricated by means of a pump and sump. The general arrangement can be seen from the illustrations. It will be noticed that the centre length of mill shafting has been replaced by a length of increased diameter shaft on which the solid chain wheel has been fitted.

With the object of obtaining a large degree of interchangeability and to reduce the quantity of spares to be carried, the motors were standardised as far as possible, and actually there are only five different sizes of motors employed in both the mills. The different motors comprise the following :—

Seven 450 h.p. asynchronous-synchronous motors for the spinning drives (one spare).

Six 300 h.p. slipring induction motors for driving softeners, breakers, interfinisher and finishing cards.

Six 200 h.p. slipring induction motors for driving softeners, teasers, drawings, rovings, etc.

Nine 150 h.p. slipring induction motors for driving looms, calenders and finishing machinery.

Nine 50 h.p. slipring induction motors for driving press pumps, sewing departments and workshops.

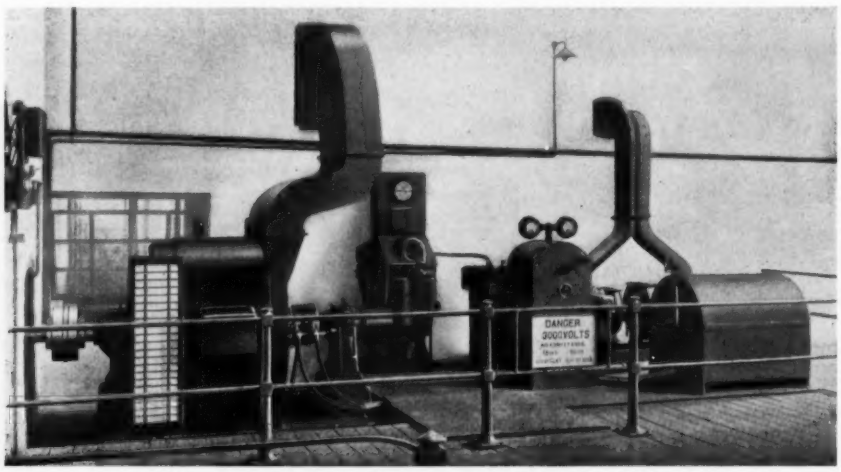


Fig. 5.—450 H.P. 3,300 volt asynchronous-synchronous motor driving line shafting for spinning machinery. The transformer and automatic motor generator set for motor excitation may be seen in the background.

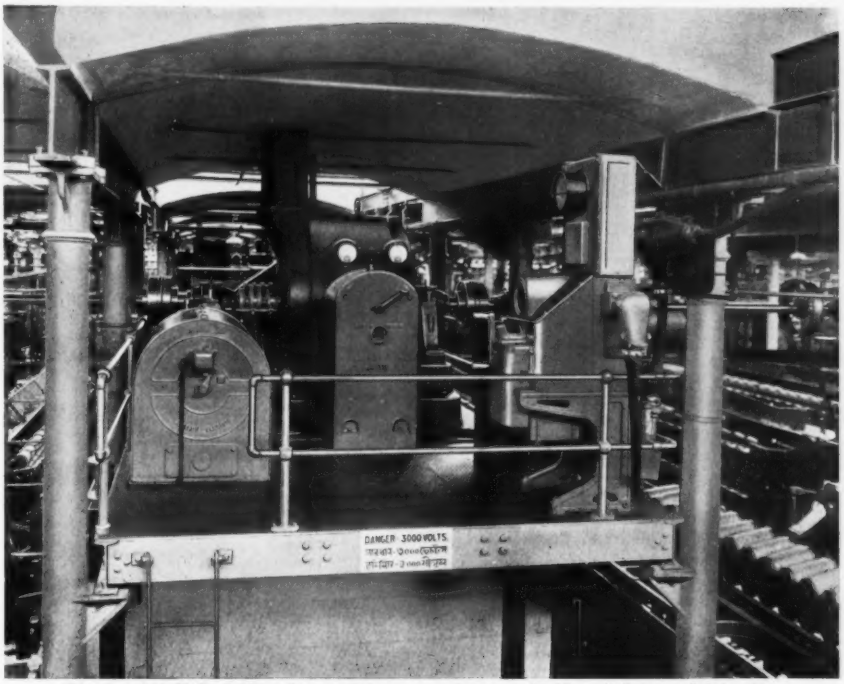


Fig. 6.—450 H.P. 3,300 volt asynchronous-synchronous double-ended motor driving line shafting for spinning machinery.

The horse-power of the motors installed aggregates 7,500 h.p.

In the case of the motors for driving the spinning line shafts a number of considerations had to be taken into account. One of the main lines (E. shaft), running at 210 r.p.m., was arranged for double-belt driving to the frames, and the calculated load on the shaft was 830 h.p. If a single motor were used, it would necessitate a somewhat larger size than was considered desirable. It was further appreciated that with the more even torque that could be obtained from the electric drive, the spinning speeds could be increased. As the latter would in any case involve a change in the belt drives, it was decided to go still farther and raise the speed of the line shaft itself and to split this line shaft into two at the centre. This was carried out, and the new line shafting was driven at 500 r.p.m. by direct-coupled 450 h.p. asynchronous-synchronous motors, one being erected in the centre pass in a similar manner to the other motors, while the other end-driving motor was installed in the engine room, as illustrated in Fig. 5. In the case of the " F " spinning line shaft in each mill, only single belt drives were used, taking half the power of the E. line. This was met by using the same type of motor, which was provided with double shaft ends, on a centre pass platform and direct-coupling it to the line shaft at each end, as shown in Fig. 6.

The Calcutta Electric Supply Corporation rates take into account not only maximum demand and load factor, but impose a surcharge on any installation having a power factor worse than .95 lagging. For this reason the 450 h.p. asynchronous-synchronous motors were designed to run at a leading power factor which would enable the figure of .95 to be obtained on the whole installation. The degree of power factor correction on these motors is controlled by the exciter regulation, so that actually the optimum value which gives the best performance and efficiency can always be obtained.

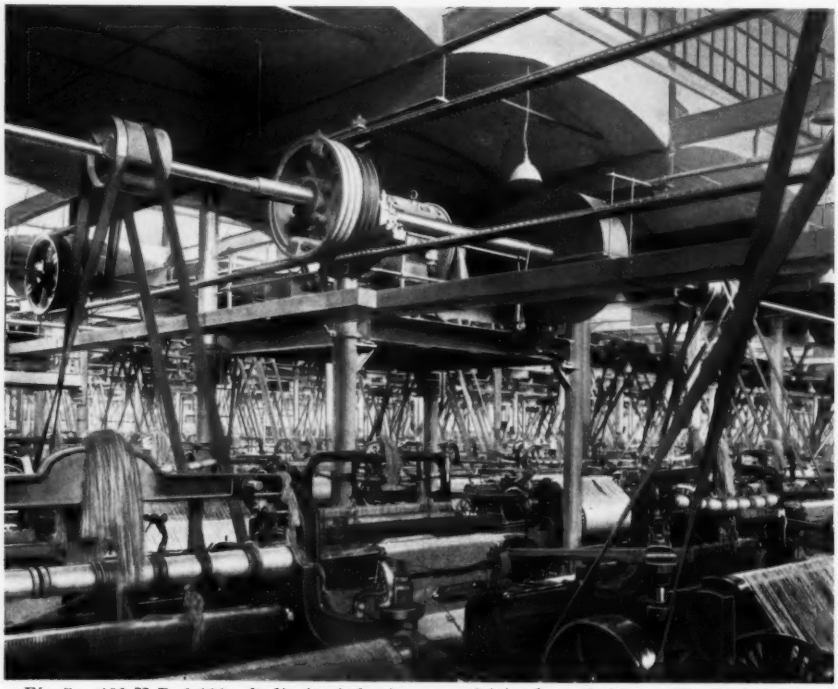


Fig. 7.—150 H.P. 3,300 volt slipring induction motor driving loom shafting. The Dick-Balata subsidiary drive to adjacent line shafts can also be seen.

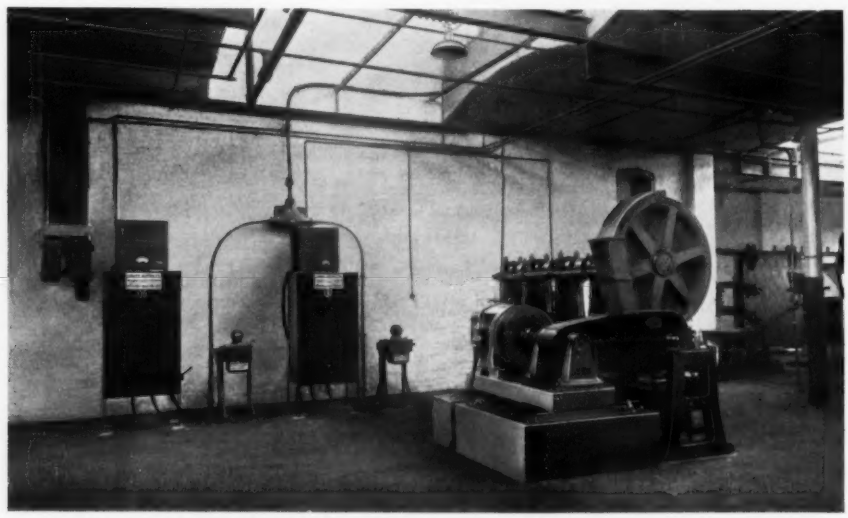


Fig. 8.—50 H.P. 400 volt slipring induction motor driving press pump. Contactor type control gear and starters for two similar sets may be seen in the background.

Owing to the space limitations previously referred to, the exciters were not mechanically coupled to the motors, but were direct-coupled to suitable squirrel-cage motors. These small motors took their supply from an auxiliary transformer stepping down pressure from 3,300 volts to 400 volts. The transformers are connected on the high tension side to the main motor stator control, so that when the latter is closed the exciter set automatically starts up and is switched into the rotor circuit when the main motor is up to speed.

In the case of the loom drives at the factory end, 150 h.p. induction motors were used, each driving three line shafts, the centre-shaft being chain-driven from a platform-mounted motor and the two shafts on either side, at approximately 11 feet centres, being driven by " Dick-Balata " vee-shaped belts from a double pulley on the centre shaft. The arrangement of this drive can be seen from Fig. 7.

An interesting application is the method employed for driving the press pumps. Originally these were belt-driven with fast and loose pulleys under the control of the press operatives. These were rearranged for a chain drive from a 50 h.p. slipring induction motor mounted on a compact masonry plinth close to the pump bedplate. The motors are controlled by automatic step by step contactor type starters. The press pumps are under the complete control of the operators by means of stop and start push buttons mounted in convenient positions.

With the method of pressing employed in the mills the motors are required to stop and start very frequently (as much as 20 times an hour), and the operators are not skilled men, being usually of the coolie class. It will be appreciated, therefore, that this automatic control affords a considerable saving in time and avoidance of overloading, due to the theoretically correct starting time which the automatic starters ensure. The drives and contactor panels are illustrated in Fig. 8.

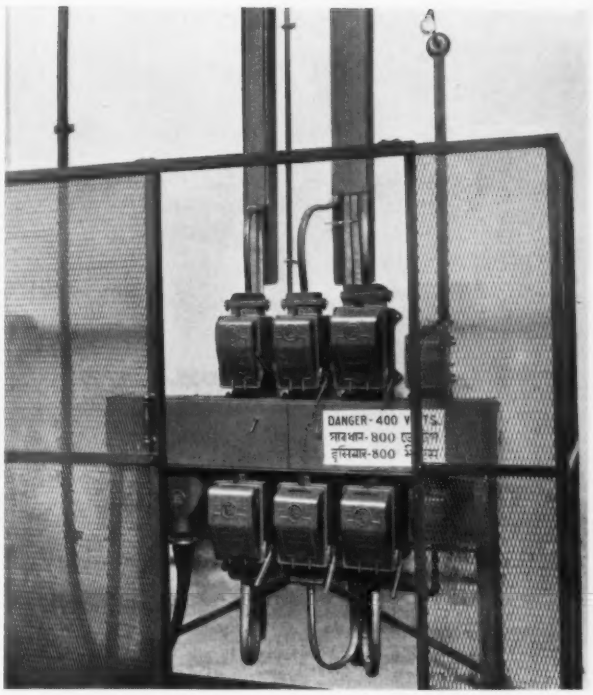


Fig. 9.—Combination fuse switchboard for mill lighting distribution.

Mill Lighting.

The contract also included the changing over of all the lighting circuits in the two mills from D.C. to A.C., the previous supply having been taken from small steam-engine-driven generators, which were dispensed with in the conversion. The original mill distribution feeders were incapable of dealing with the much heavier fault kVA. made available by the A.C. supply, and new ironclad switchboards fitted with high rupturing capacity combination fuse switches were installed. One of these switchboards is shown in Fig. 9. The metal casing over the lead-covered cables was fitted in order to comply with the Indian Electricity Rules.

Sub-Station.

A general view of the sub-station is shown in the frontispiece, and it will be seen that a building which was originally part of the mill has been

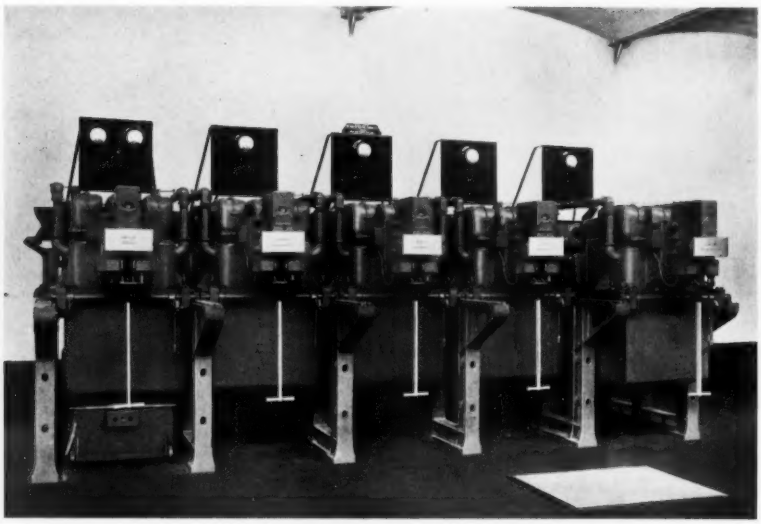


Fig. 10.—22,000 volts Metalclad compound filled switchboard, type O.L.E. 2A. Rupturing capacity 350,000 kVA.

used ; the plant, however, has been disposed of in a manner resulting in economical cable runs, but at the same time giving full access to all the gear.

The supply is brought into the sub-station by duplicate cables at 20,000 volts, and is taken from the Supply Company's metering panel to the incoming panel of the main mill switchboard. This consists of a 5-panel board of compound filled O.L.E. 2A type switch panels, illustrated in Fig. 10, with a rupturing capacity of 350,000 kVA. Feeders are taken to four transformers, two of 5,000 kVA., stepping down to 3,300 volts and giving supply to all the mill motors at 150 h.p. and upwards, and two smaller transformers rated at 1,000 kVA., each stepping down to 400 volts to supply all the smaller motors. The neutral point on the L.T. side is brought out to provide the A.C. lighting supply for the mills.

Owing to the cost of converting all the D.C. fans and other apparatus in the residential quarters and certain other small circuits, such as the electrically operated jetty cranes, it was decided to retain D.C. for these. This was done by utilising three of the existing generators, which were disconnected from the original steam drive and installed in the sub-station and direct-coupled to three 120 h.p. Kosfi motors. These motors serve to take care of the power factor at night time and at periods when the asynchronous-synchronous motors in the mill are not working.

Each of the different size transformers is capable of meeting the full load demand of the mills, and there is therefore a 100 per cent. standby in this respect.

As elsewhere in the mill, the roof of the sub-station was very low, and a modification was therefore made to the centre. Lifting beams were erected at such a height as to enable the transformer cores to be lifted clear of the tanks. Also, owing to the low roof and absence of outside ventilation, there would have been a tendency for the air temperature to become excessive ; to overcome this, propeller and extractor type fans were placed in the end walls. During the last hot season it was proved that with the aid of these fans the room temperature could be kept within reasonable limits.

Cabling.

The cabling in the sub-station was carried out in trenches by means of paper-insulated lead-covered cables supported on cleats, while the feeders to the various switches in the mill from the 3,300-volt switchboard consisted of paper-insulated lead-covered single wire armoured cables.

Owing to the congestion of the machinery in the mills, it was impracticable to run these latter cables in floor trenches. Economical runs could have been obtained by running the cables on the outside of the flat roof, but owing to the excessively high sun temperatures, which may reach 160 deg. F., this was also ruled out. The main cabling was therefore carried on a light fabricated

frame work supported from the roof members. A straight run was taken from the sub-station the entire length of the two mills, the run being diverted at right angles at the centre pass in each mill. At these points the cabling was run on hangers from the roof beams, a feed being dropped on to each platform. These runs are inconspicuous, but at the same time ample ventilation for the cable exists.

Fig. 11.—3,300 volt Truck type switchboard.

Changeover.

It was decided that the actual changeover to electric drive should take place gradually and at week-ends. In this manner the entire conversion was effected without losing a minute of actual production working. The importance of this fact will be understood when it is remembered that at the time the Jute Mills Association were limiting the working hours to 40 per week, and had the process of changing over encroached on these hours, a very serious loss to the mills would have been sustained. In this connection it may be mentioned that when the associated millwrighting work was being done it was discovered that in certain areas a considerable ground subsidence had taken place since the mills were first built. This necessitated the entire re-alignment of certain line shafts, which work had to be carried out during the week-ends.

Owing to the type of drive, the complete absence of any ropes whatsoever, and the special care which has been taken over the alignment of shafting, the energy consumption per loom has reached what is believed to be a record low figure for any of the electrified mills on the river.

One of the advantages which may be mentioned of the policy of splitting up the electric drives into comparatively small groups is the facility which is given to the maintaining of the highest possible load factor. An example of the rates charged by the Supply Company is given below, and it will be immediately seen that it is most important to keep the average demand as closely as possible to the maximum demand.

Supply Company's Rates for Loads between 3,500 and 4,500 kW.

Load Factor.	Rate per unit.	
30%	.383 anna	The value of the
35%	.343 ,,	anna is approxi-
40%	.318 ,,	mately one penny.

Power Factor surcharge .0025 of an anna per unit for every 1% below 95%.

In an Indian jute mill and during the monsoon period rapid changes of humidity may occur, and during periods of heavy rains the moisture in the air may have immediate effect on the spinning frames and result in machines taking anything up to 15 per cent. higher load than normal. If precautions were not taken this might cause a sudden increase in the maximum demand and a corresponding reduction in the load factor, which, in turn, would have the effect of increasing the cost of all the units consumed during the month. With the suitable grouping of various motors,

however, this can be overcome, and it is frequently permissible, without affecting actual production to shut down various drives for a short period to prevent the maximum demand recording instruments from registering a total seriously in excess of the average demand.

The conversion of the installation was completed at the commencement of last year and the final switching-on ceremony was carried out by Mr. Wild, a partner in the Managing Agents' firm, on the 25th March, 1936.

The entire contract for the supply and erection of all the materials was entrusted to the English Electric Company, whose sub-contractors included Messrs. Douglas Fraser & Company for the supply of all shafting and millwrighting work, Messrs. Hans Renold for the chain drives and Messrs. Siemens Brothers for the cables.

Some Considerations in the Testing and Application of Modern High Rupturing Capacity Switchgear.

By A. R. BLANDFORD, Chief Engineer and Manager, Switchgear Department.

Oil Circuit-Breakers have been produced in this country under two definite Specifications, namely, B.S.S. 116/1923 and B.S.S. 116/1929. These two Specifications were introduced prior to the availability of testing stations or any other organised method of proving the ability of circuit breakers to deal with all types of faults.

Owing to the lack of such testing facilities circuit breakers have in the past been rated generally upon empirical formulæ and field experience. With the introduction of testing stations the handicap to progress has been removed, permitting research to be undertaken which has resulted in the development of new methods of circuit-making and circuit-breaking. It also has paved the way for establishing a standard of performance which has been proved will meet service conditions.

This new standard has not only been accepted and agreed for Great Britain but has also received international recognition and agreement.

Some of the more important points brought out in the specification are here summarised and discussed in greater detail in the succeeding paragraphs.

(1) Limitations of ampere short-circuit rating.

(2) Tests at other than the full rated rupturing capacity.

(3) Full cognizance of the importance of recovery voltage.

(4) The restriction of the value of the D.C. component for determining the breaking capacity performance on average speed breakers, with provision for inclusion of the D.C. component for high-speed breakers.

(5) Control of test plant decrement.

Limitations of Ampere Short-circuit Rating.

In the past it has been customary for manufacturers to offer and actually instal circuit-breakers having very high rupturing capacity rating of the order of 1,500,000 kVA. at comparatively low voltages, say 6,600. A study of the amperes to be dealt with in a breaker of this size will show that the breaking current is 130,000 amperes, and the making current could be of the order of 330,000 peak asymmetrical amperes.

The mechanical stresses encountered in designing a circuit breaker to withstand the forces which would be set up by currents of this magnitude place such circuit breakers beyond economic design and construction. Closing forces for operating under these conditions would be extremely high and create difficulty in producing a satisfactory mechanism, especially in view of the fact that the circuit breaker must close during a large percentage of its life at practically no load, giving a surplus of power which would produce very severe shocks upon the whole structure.

The thermal capacity of the contacts is yet another very difficult problem to overcome, as obviously with making currents of this high order it is very difficult to arrange that contracts immediately they " make " with comparatively small pressure and reduced contact area, will at the same time carry these heavy currents without tendency to weld.

With these facts in mind, the maximum rupturing capacity ratings provided for at specified voltages in the future will be of the following order :—

6.6 kV	500 m.V.A.
11 kV.	750 m.V.A.
22 kV.	1,500 m.V.A.
66 kV.	2,500 m.V.A.

It will be appreciated that in order to keep within the rupturing capacity values enumerated above, it will, in a large number of instances, mean a rearrangement of systems introducing reactors, and possibly the introduction of transformers for the purpose of stepping up to higher voltages.

Tests at other than the Full Rated Rupturing Capacity.

In earlier Specifications no consideration had been given to tests other than at the full rated rupturing capacity. It is well known that the length of an arc drawn by a circuit breaker can be appreciably longer at lower kVA. values of say 10 per cent. to 30 per cent. of the full rating. With this knowledge it is now intended that due consideration shall be given to the behaviour of the circuit-breaker under these conditions of reduced kVA., and additional tests at 10 per cent., 30 per cent. and 60 per cent. of the full rating have therefore been introduced into this Specification.

Typical curves for a modern circuit-breaker fitted with arc control device are shown in Fig. 1, indicating how the arc length varies with the current broken.

It will be realised that many of the existing circuit-breakers in service to-day have not been tested under these conditions, and consequently it is not improbable that at some of the lower ratings the arc length may be maintained throughout the full travel of the circuit-breaker,

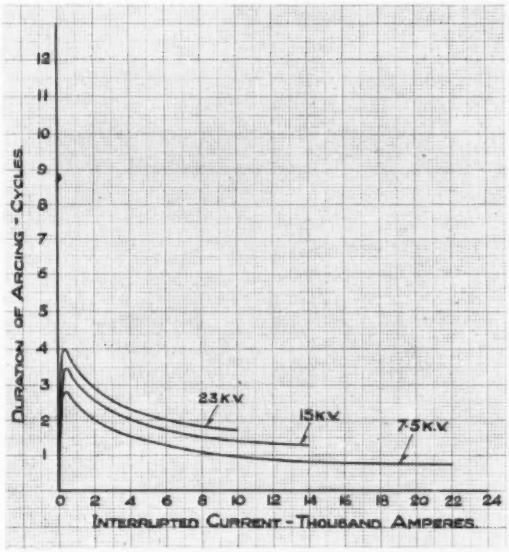


Fig. 1.—Typical curves showing relation of arcing time to current interrupted.

thus limiting the rupturing capacity of such a circuit-breaker to a very small value.

This fact cannot be over-emphasised, and it is responsible for some of the failures which have occurred on existing circuit-breakers under comparatively light fault conditions. It is impossible for designers to estimate the general behaviour of circuit-breakers in this respect, and the only way of determining the characteristics of the breaker is by actual test.

Full Cognizance of the Importance of Recovery Voltage.

The rupturing capacity of a circuit-breaker when interrupting a short-circuit depends not only upon the current in the arc, but also upon the recovery voltage of the circuit to which it is connected. It is necessary for Engineers to predict the recovery voltage which will obtain on their system.

For single-phase short-circuits the recovery voltage is lower than the initial voltage only by the reduction in useful flux in the generating plant due to the armature reaction of the short-circuit current.

With three-phase short-circuits, the recovery voltage of the first phase to clear is modified,

not only by the reduction in flux due to armature reaction, but also by the nature of the ground connection.

The new Specification takes into account these facts and when circuit-breakers are tested single-phase, which is a permissible method when each phase is contained in a separate tank, the recovery voltage must be on the basis of 50 per cent. above the rated phase voltage in order to allow for the fact that any one of the three poles may be the first to clear the short-circuit.

Although this additional voltage is used for the purpose of test, it is not included in the interpretation of the performance of the breaker from the test records, the value of the phase recovery voltage only being used for this purpose.

Further, definite limits of variation from the rated voltage are specified in order to ensure that the circuit-breaker will operate satisfactorily under average service conditions.

THE RESTRICTION OF THE VALUE OF THE D.C. COMPONENT FOR DETERMINING THE BREAKING CAPACITY PERFORMANCE ON AVERAGE SPEED BREAKERS WITH PROVISION FOR INCLUSION OF THE D.C. COMPONENT FOR HIGH-SPEED BREAKERS.

When short-circuits arise on either a three-phase or single-phase system, the current at the outset will in general be made up of two components, namely—

(*a*) A direct current component.

(*b*) An alternating current component.

The latter is independent of the particular point on the voltage wave at which the short-circuit occurs. The former is dependent not only upon the value of the alternating current component, but also upon the point of the cycle at which the short-circuit occurs.

Direct Current Components.

Considering the alternating current component alone, this would require that the current increases instantaneously from zero to some finite value except when the short-circuit occurs at a point on the cycle at which the current would normally be zero. Owing to the presence of inductance in the armature circuit the current cannot change instantly, therefore, an equalising direct current flows of such a magnitude as to make the total current zero when projected back to zero time. This direct current then falls exponentially at a rate governed by the direct current time constant *Ta.*

Alternating Current Component.

An alternating current component can be divided conveniently into a sub-transient and a transient component. If the envelope of the current wave is projected back to zero time neglecting the first few cycles having a very rapid decrement, a transient current is obtained. The value of this component is equal to the voltage divided by the transient reactance. The difference between the total current and the transient component is the sub-transient component. The total current has a value equal to the voltage divided by the sub-transient reactance. Since the sub-transient component of the current is maintained by a flow of induced current in the damper windings, which usually have a fairly high resistance, the time constant for the A.C. component is usually small and the consequent current decrease very rapid for the first few cycles.

The limitation of the D.C. component in the calculation of the rupturing capacity of average-speed breakers is justifiable as in practically all cases the current will be reduced to the A.C. component only by the time the contacts of the circuit-breaker part.

Testing circuit-breakers under the foregoing conditions increases the duty on the circuit-breaker in that the rate of rise of recovery voltage is increased and also the power factor of the circuit is decreased, both of which conditions increase the difficulties of circuit rupturing.

CONTROL OF TEST PLANT DECREMENT.

By referring to the description given under the heading of Item (3) it will be understood that if the voltage before short-circuit and after short-circuit is defined, this is a very convenient means of assessing the current decrement obtained on short-circuit tests because the current during short-circuit will be proportional to the voltage.

When studying tests from this point of view this factor is of the utmost importance. For want of a better means the amperes interrupted

by the circuit-breaker are defined in all specifications as being the amperes at the instant the contacts part.

Therefore unless this voltage decrement is defined, should a small testing generator be used for the purpose of tests, it would be possible, owing to the reduction in useful flux in the generator to cause a heavy voltage decrement with a corresponding reduction in the current between the time the contacts part and the time when the arc is extinguished. Under these conditions a circuit-breaker could be given an erroneous rating even though the recovery voltage would be of the correct value.

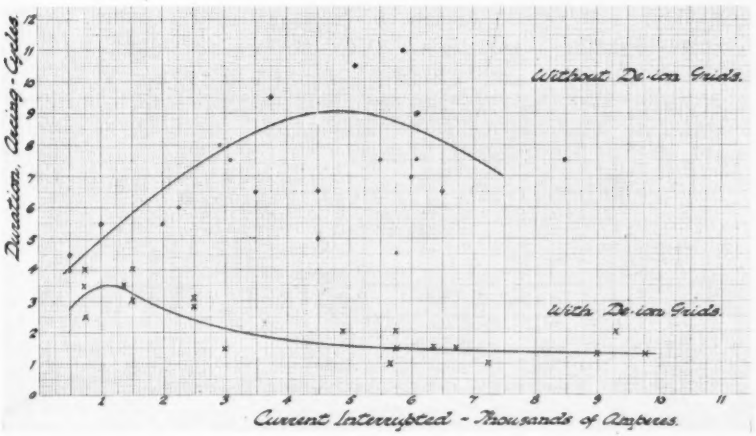


Fig. 2.—Typical curves showing relation of arcing time to current interrupted, with and without De-ion Grid contacts.

Having stated the general trend in which Standard Specifications are being modified to ensure that circuit-breakers will satisfactorily meet service conditions, it will be interesting to examine the methods which have been adopted in this country to bring about the necessary improvements in order to comply therewith.

One of the most important developments in circuit-breaking is the introduction of the arc control device. Several types of these are now available and all aim at reducing the arc energy with consequent reduction in stress and depreciation of contacts and oil. It has been demonstrated by tests that such devices can be operated satisfactorily from 6,600 volts up to voltages of any practical magnitude.

The advent of these devices has done much to stabilize considerably the operation of oil-circuit-breakers, producing very consistent results over wide ranges of short-circuit values. In fact it is the Author's definite opinion that a consistently satisfactory oil-circuit-breaker without arc control device cannot be produced for voltages of 33 kV. and upwards.

Dealing with the question of consistency of performance, it is interesting to compare a number of tests made on a 750,000 kVA. 33 kV. oil-circuit-breaker fitted with arc control device with a plain contact circuit-breaker of 6,600 volts rating, the tests ranging from 10 per cent. up to maximum rupturing capacity.

The curves illustrated in Fig. 2 show these comparisons, and it will be seen that the arcing times for the circuit-breaker fitted with the arc control device approximate closely with the figures given in the curve shown in Fig. 1. It will be noted that the arcing times at the lower rupturing capacity of the plain contact circuit-breaker are excessively long, and this amplifies the statement made earlier that many of the existing circuit-breakers which have not been tested under lower rupturing capacity conditions are liable to failure on this account.

This is a very important point, as when Supply Engineers are considering the existing circuit-breakers on their system, it is sometimes assumed that where the available short-circuit kVA. is very much lower than the full rating of the circuit-breaker, there is an ample margin of safety which in actual fact does not exist.

It will also be appreciated that with the more consistent arcing times it is definitely possible to secure finer settings of the protective relays and thus ensure that the fault is interrupted in a minimum of time, preventing as far as possible undue disturbances to the system.

Tank pressures are also considerably decreased by the application of arc-control devices, and it is almost inconceivable to-day that large numbers of circuit-breakers are still being purchased and installed which rely for their successful behaviour upon what the author considers to be " blacksmith methods."

A great deal of consideration has recently been given to the problem of the safety of operators, and when it is appreciated that it is possible to instal circuit-breakers having maximum tank pressures of the order of 20 to 30 lbs. per square inch, it is difficult to believe that this question of safety is really being treated seriously when one finds that circuit-breakers are being installed with tank pressures of the order of 10 times this value for the same rupturing capacity.

In the author's opinion, low tank pressures should be made an essential condition of any Purchasing Specification.

It must be remembered that exigencies frequently prevent regular examination and maintenance, and often after paying visits to old installations it has been discovered that tank bolts are not properly tightened, and under such conditions a circuit-breaker designed for heavy tank pressures might release a large quantity of burning oil, resulting in fatal injuries to the operator.

While dealing with this point it might be as well to consider the two main forms of tank joints which are in use to-day. Certain breakers rely upon a machined flanged tank joint, while others are fitted with gaskets. The author considers the latter method should be deprecated from two points of view. It is impossible to find a satisfactory gasket having sufficient resiliency and which will not, in the course of time, suffer from a natural deformation under pressure. This means that with gasket joints it should be a regular operation to tighten all the tank bolts to ensure that the joint is tightly held.

If tank bolts are allowed to become loose with a gasket joint, there is always the danger of the gasket being blown out under pressure and the possibility of burning oil being discharged over the operator. It is known that a number of cases of this kind have occurred.

From this it will be realised that an efficient arc-control device assists materially in eliminating danger to the operator, and especially in those instances where gaskets are used for the tank joints.

The essential features of an efficient and satisfactory arc-control device are :—

(1) Ample mechanical strength.
(2) Limited internal pressures.
(3) Sufficient margin of length over and above the length of the arc.
(4) Definite control of the arc.
(5) Readily replaceable sections.
(6) Facilities for the inspection of contacts and also the interior of the device without dismantling.
(7) Readily replaceable arcing contacts.

The English Electric Company's arc-control device, de-ion grid contacts, meet all of these conditions as described below :—

(1) Ample Mechanical Strength.

Mechanical strength of the device is determined by testing at an ampere capacity very much in excess of that adopted as its rating.

(2) Limited Internal Pressures.

With the de-ion grid arc-control device there is no attempt made to enclose the device with a view to setting up high internal pressure, and the device is open-vented both at the top and the bottom.

(3) Sufficient Margin of Length over and above the Length of the Arc.

A maximum arc length of 50 per cent. of the length of the de-ion grid is allowed for the length of the arc at full rupturing capacity.

(4) Definite Control of the Arc.

This, unlike any other arc-control device, is achieved magnetically.

(5) Easily Replaceable Sections.

The de-ion grid arc-control device is built up of independent sections, and if, after the course of years of service it is thought necessary to replace the top section, which is subject to the greatest arcing temperature, this can be achieved by transferring the top section to the bottom of the device, and *vice versa*, thus effecting a saving in maintenance costs.

(6) Facilities for Inspection of Contacts and the Interior of the Device without Dismantling.

By removing the two hexagon headed screws A and A1 (*see* Fig. 3), the fixed contacts and the condition of the interior can be readily examined.

(7) Readily Replaceable Arcing Contacts.

The removal of the hexagon-headed screws referred to above allows the arcing contact B (*see* Fig. 3) to be inspected and this can be readily replaced at the same time if necessary, without further dismantling.

Not only has considerable progress been made with the art of circuit rupture by the introduction of the arc-control device, but a good deal of research and development has also taken place in connection with the question of closing the circuit. This was necessary, as it has been discovered that many of the old forms of contacts were prone to welding-in on making the heavy currents required on modern circuit-breakers. Improvement and progress has been achieved mainly by altering the shape and design of both fixed and moving contacts, and further by the application of arc-resisting alloys which have a much higher melting temperature and are less prone to welding.

In addition, the rate at which the circuit-breaker closes, when closed other than by hand, has been increased to ensure that the maximum area of contact is obtainable in the minimum time.

With these improvements and other details of a minor nature, it can now be claimed that the oil-circuit-breaker is a satisfactory piece of apparatus providing all the safeguards demanded by modern Supply Undertakings.

It is acknowledged that certain failures with switchgear have been experienced of late, but generally these failures have not been as a result of the failure of the circuit-breaker to perform its duty, but are more of the nature of insulation failures of the apparatus itself or the auxiliary apparatus which forms part of the equipment.

Where breakdowns have occurred due to the circuit-breaker having failed to perform satisfactorily its interrupting duty, the author is unaware of any single case where this has taken place on a circuit-breaker which has been proved by test con-

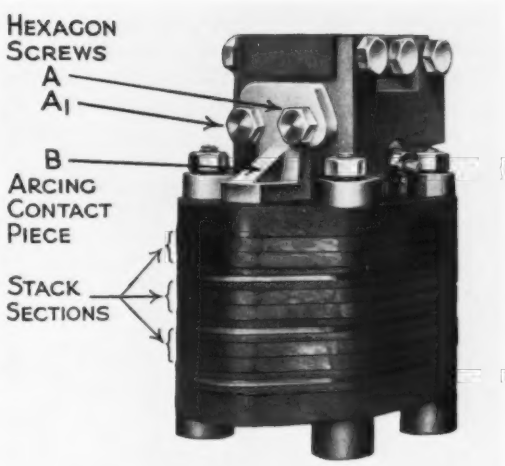


Fig. 3.—Typical Assembly of De-ion Grid contact.

forming to the specification shortly to be issued and where it was acknowledged that the circuit-breaker was in every way equal to its duty and rating.

It is not in every case that existing circuit-breakers could be replaced by up-to-date circuit-breakers without involving further modifications to the arrangement of the system. It was explained earlier that economically, circuit-breakers have a limited ampere capacity, and when this value is reached it involves either the introduction of reactors or reducing the rupturing capacity or alternatively increase the voltage to bring the ratings within the limited ampere capacity.

In some of the failures which have occurred, prolonged shut-downs have resulted, and in some cases the fire damage has been very heavy. It will be understood that with any apparatus of the type under discussion employing insulation mediums, it is impossible to guarantee that failures cannot and will not occur. Therefore it becomes necessary to examine the layouts of Switching Stations and to see that in cases of failure the fire hazard is reduced to a minimum.

Some work in this direction has been achieved by the introduction of circuit-breakers containing a comparatively small quantity of oil in the circuit-breaker tanks, generally at the expense of safety factors in the circuit-breaker. In the author's

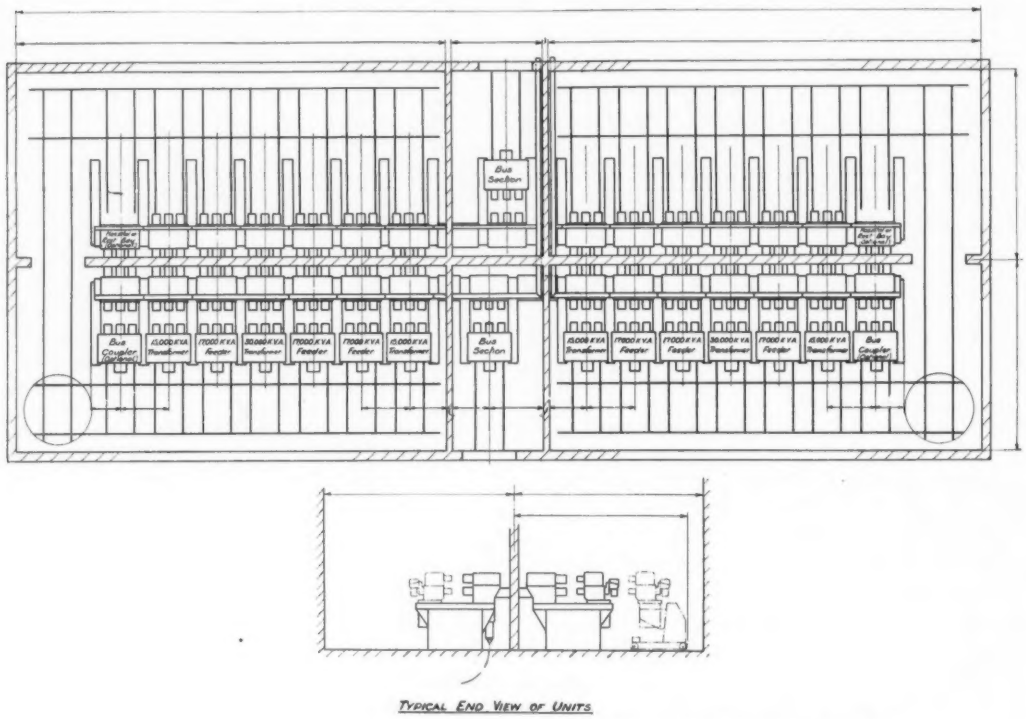


Fig. 4.—Typical Arrangement of Substation using Metalclad Switchgear (Plan and End View).

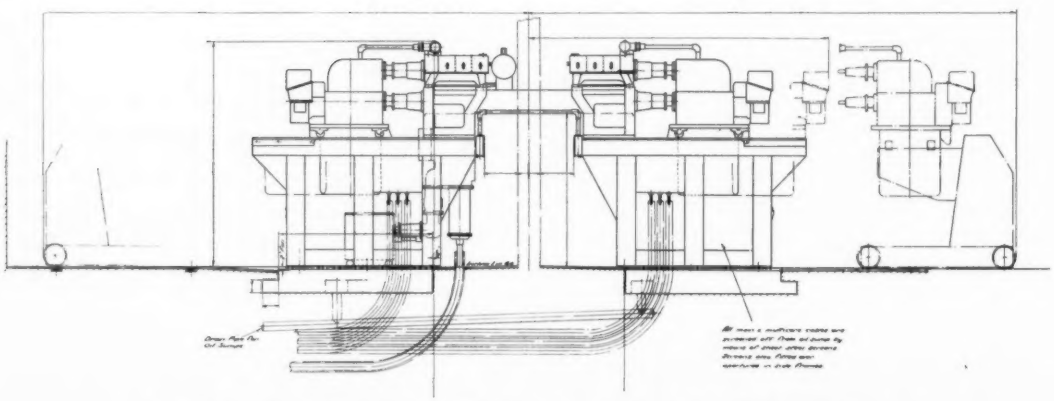


Fig. 5.—Typical Arrangement of Substation using Metalclad Switchgear (Elevation).

opinion it is entirely wrong to proceed along the lines of reducing tank capacities in an attempt to decrease the fire hazard. This type of circuit-breaker usually employs a single-break per pole, which is reverting to types that were in common use many years ago.

It might be claimed that the single-break circuit-breaker can be made to rupture the same value of kVA., thus giving the same safety factors as can be obtained with a double-break circuit-breaker. This claim is ethically unsound as naturally with a double-break circuit-breaker there is employed two independent arc-control devices and in the event of either of these becoming damaged from any cause whatsoever, the remaining arc-control device must be and is quite capable of dealing with the full-rated rupturing capacity.

The author has seen evidence on tests in more than one case of one of the arc-control devices having been damaged so as to render it practically useless; the circuit-breaker, however, has behaved admirably under the control of the remaining healthy device.

This is a fact of outstanding importance and must not be overlooked when reducing the size of the circuit-breaker tanks in order to keep down oil quantities. It is not so very long ago when circuit-breakers which had the largest tanks were considered to be the most reliable, and there is still very much in favour of this viewpoint.

It is recommended that rather than adopt these measures, Supply Engineers should realise the possible failure of their switchgear and take steps in the layout of their station to see that the effect of such damage is kept down to a minimum.

The methods recommended in this direction are as follows :—

(1) The Application of Busbar Protection.

Such protection will guard against excessive damage due to the more common cause of circuit breaker-failures, i.e., insulation breakdown. With modern circuit-breakers of reasonable capacity, the busbar systems and inter-connections are completely phase separated, and with the application of busbar protection when the neutral of the system is earthed, either through an earthing transformer or an earthing resistance, it is almost impossible to allow of excessive earth currents for prolonged periods. This protection goes far to minimise fire risks.

(2) Installation of Fire Fighting Apparatus.

The buildings should be suitably arranged for saturating with $C.O._2$, which is released at some predetermined temperature rise.

(3) The Layout of the Switchgear can be considerably improved compared to that which has been adopted as a Standard Practice in the past.

(4) Suitably drained Oil Sumps and Subdivision of the Station should be provided.

In connection with the last two items, a scheme is outlined in Figs. 4 and 5, which shows what is in the author's opinion, a very definite step in the right direction, and while this does not claim to prevent fires, it rather caters for the supply being maintained in the event of fire taking place.

Briefly, the scheme is suitable for a duplicate busbar layout diagrammatically shown in Fig. 6, and more particularly suited to cases where there are duplicate feeders. It will be seen from the examination of the foundation plan, Fig. 4, that the scheme briefly comprises four independent switch houses with two separate bus section switch compartments. The incoming feeders are, as far as possible, placed equally on each side of the section switches. Duplicate circuit-breakers can be provided for the feeders, or alternatively the method of bus selection can be

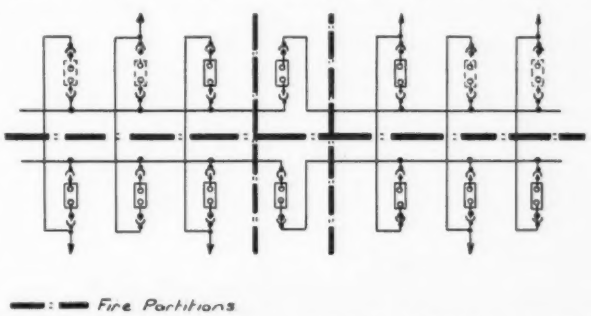


Fig. 6.—Typical Diagrammatic Arrangement of Switchgear showing fire sectioning.

by truck or crane which moves one moving portion from one side of the building to the other.

It is recommended that although the outgoing feeders need not be equipped with duplicate breakers, that the incoming feeders should be so equipped. It is also recommended that two travelling breakers should be provided for the purpose of changing over one set of busbars to the other without interrupting the supply to the outgoing feeders.

The outgoing feeder cables are arranged similarly to the incoming cables on each side of the bus section switches, and in addition only 25 per cent. of the feeder cables enter each of the four switch houses.

With this arrangement if a fire should take place in any one of the four switch houses, only 25 per cent. of the cable output of the substation would be affected.

The scheme is not expensive and the cost of the apparatus compares very favourably with the orthodox method of busbar selection where the busbars are situated one above the other. With the latter type of arrangement it is impossible to place any degree of faith in the stand-by busbar, other than for testing or switching purposes. In the event of fire it is quite understandable that the whole of the busbar system is likely to be deranged and out of commission, thus resulting in a complete shut-down.

Current-Limiting Reactors.

Their Application to 132-kV. Systems.

By R. M. CHARLEY, M.C., B.Sc., M.I.E.E., Mem.A.I.E.E.

(*Reprinted from "The Electrical Review," 12th March*, 1937.)

Current-Limiting Reactors have been applied to alternating current systems for many years. Their earliest use was for the purpose of increasing the circuit impedance of a feeder, or distributor, to a value consistent with the safe rupturing capacity of the switchgear installed. This condition arose largely because it was common practice to specify comparatively low impedance for transformers in order to secure the advantage of better voltage regulation. In later years, however, this feature was considered of less importance than the necessity for building the transformers with sufficient reactance to render them self-protecting under short-circuit conditions. The problem of voltage regulation has been overcome by the installation of equipment in the form of on-load tap-changing on main transformers or some type of separate voltage regulator.

It is interesting to note that in the light of recent investigation into the true rupturing capacity of switchgear, values allocated to switchgear built some years ago are found to be too high. Consequently, reactors must be installed, or alternatively, in many cases the actual rupturing capacity of the circuit breakers may be increased by modifying their construction, as, for example, by the replacement of the contacts with new ones of the " De-ion Grid " type.

Another application of reactors is to insert them between sections of the busbar of a large power station, where even the high reactance of the generator and step-up transformer is not sufficient to restrict the short-circuit current to a safe value in the event of a fault occurring in one section, in which case all other connected generators would feed into it. A typical example of this scheme is that of the Barking Power Station where each generator is connected through its step-up transformer to a section of the 33 kV. busbar, and between sections are installed large current limiting reactors. The installation consists of seven banks of oil-immersed reactors

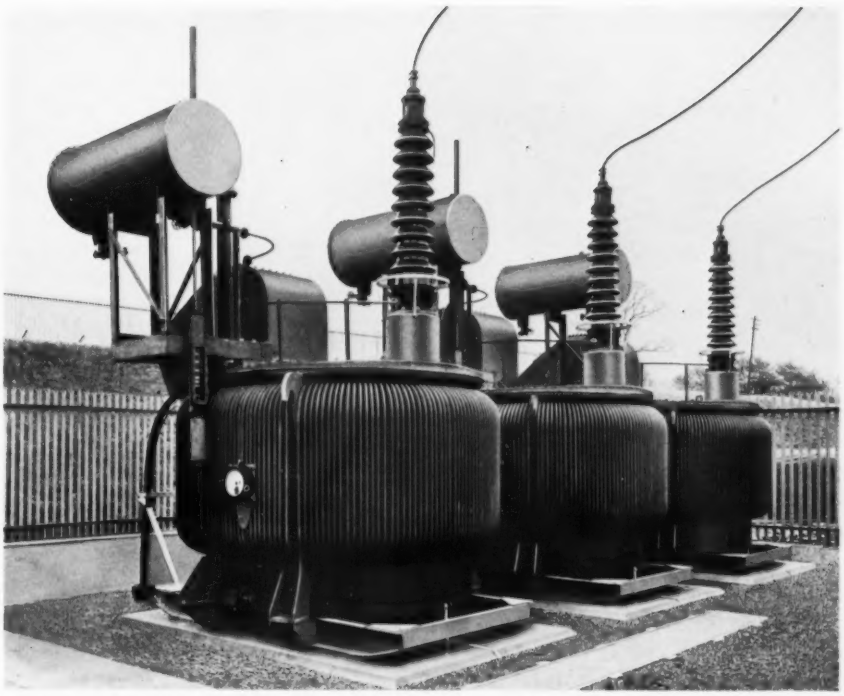


Fig. 1.—Bank of Reactors at the Central Electricity Board's Transformer Station, Northfleet.

located outside the Power Station. Each bank gives a reactance of twelve per cent. on a capacity of 50,000 kV.A. at 33 kV.

A similar use for large reactors originates from the interlinking of power systems which has been carried out on such a vast scale in recent years. The capacity of generating plant connected to the interlinked systems has reached such a huge total that, should a fault occur in a certain section, the short-circuit current fed into it would exceed a safe limit for the switchgear. To restrict this fault current to a safe value, reactors are connected between sections at carefully selected points. An example of this nature is the installation at the Grid Transforming Station at Northfleet, where two banks of reactors giving five per cent. reactance on a capacity of 50,000 kV.A. at 132 kV. are installed. A description of these units, which are shown in Fig. 1, follows.

On account of the voltage of 132 kV., these reactors are naturally oil-immersed, but this practice is sound for all reactors of whatever size or voltage. The conductor is an enamelled and paper-wrapped stranded cable. The insulation on the cable, together with the space between conductors in the coil, is sufficient to give adequate security against surge conditions. The layers are spaced in the horizontal direction by sectors, which are locked in by long vertical strips which form the axial spacers, these strips passing through slots in the sectors; both types of spacers are of fullerboard. The process of winding the coil is illustrated in Fig. 2. To facilitate the winding the axial or vertical spacers must be only an inch or so above the level of the layer being wound, but they must be continuous throughout the length of the coil; thus, at the commencement of the winding, the spacers project below the winding face-plate and are pushed upwards as the winding progresses. The coil is formed on a bakelised paper cylinder. Fig. 3 shows two completed coils.

The insulation between the ends of the coil and the clamping plates is provided by sectors

Fig. 2.—Reactor Coils in process of being wound.

and washers of fullerboard. The insulation test applied between the coil and ground in the completed reactor is 300 kV. for one minute. The coil and end insulation is clamped between steel plates tied together with phosphor bronze bolts. Although these plates are some distance from the coil, they are within the influence of the flux of the coil and consequently, eddy current losses are generated in them. The amount of the loss is reduced to a negligible value by two concentric copper rings bolted to the plate. By transformer action currents are induced in the rings and the result is to prevent to a large extent the flux from entering the steel. One of these rings can be seen in Fig. 3.

The coil is contained in a circular tank on which the radiating surface necessary to dissipate the heat generated by the normal load loss is provided by elliptical tubes bent on edge and welded into the tank side. Losses generated in the steel plate of the tank wall due to the flux of the coil are controlled by the method known as copper ring shielding.

Round the inner surface of the tank-wall opposite the winding are several copper rings, of heavy cross section. The effect of these rings is the same as that described above in relation to the steel clamping plates of the coil.

In some similar reactors designed to give 10 per cent. reactance on a capacity of 50,000 kV.A. at 132 kV., the shielding is achieved by means of the magnetic shunt principle which comprises a number of packets of laminations of transformer steel mounted radially round the inner surface of the tank, thus providing a low loss path for the flux.

The tank is provided with an oil expansion vessel with accommodation for a Buchholz Protective device and an explosion diaphragm.

The oil-level gauge (Patent No. 450,419) was described in the article "Scientific Developments in Transformer Construction" in the December, 1936 (Vol. VIII, No. 4) issue of this Journal.

Connection for the 132 kV. overhead line is made through a condenser bushing mounted in the cover of the reactor, while the outgoing con-

Fig. 3.—Two completed Reactor coils.

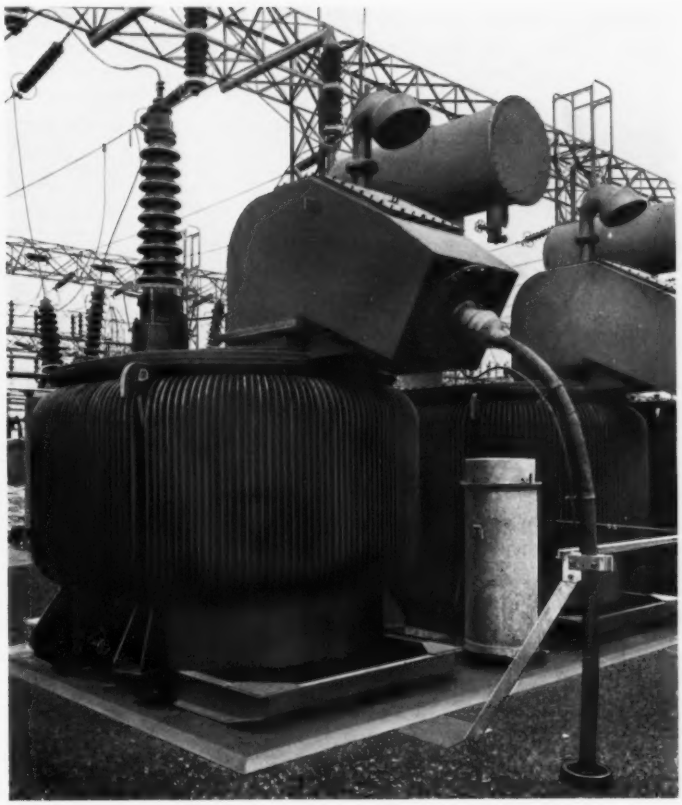


Fig. 4.—Showing cable entry of outgoing single-core oil-filled cable.

nection is made to a single-core oil-filled cable. The cable is finished in a sealing end supplied by the cable maker, and this is mounted inside a large chamber located on the tank cover, the oil in the chamber being common to the oil in the main tank. The connection from the sealing end to the coil is made by a flexible cable enclosed in a brass tube which is supported from the coil itself and is adequately braced to prevent movement under short-circuit conditions. The cable entry is seen in Fig. 4.

The loss in one reactor of the bank having five per cent. reactance on a capacity of 50,000 kV.A. is 20.5 K.W. A completely assembled coil weighs 6,500 lbs. Each unit, complete with oil, weighs 38,170 lbs.; the diameter over the tubes of the tank is 10 ft. and the height over the bushing is 15 ft.

Interesting Reactor and Transformer Installations at Brighton.

By R. M. CHARLEY, M.C., B.Sc., M.I.E.E., Mem.A.I.E.E.

The author is indebted to W. N. C. Clinch, Esq., A.M.I.E.E., Engineer and Manager, Brighton Corporation Electricity Undertaking, for permission to publish the details of the application of the reactors and transformers to his supply system

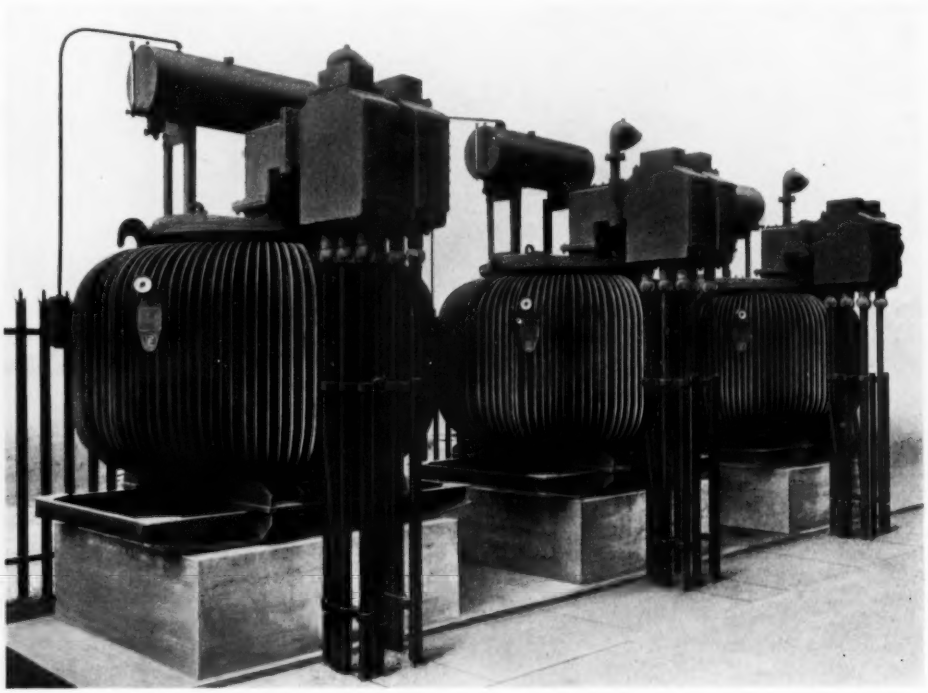


Fig. 1.—A Bank of three single-phase reactors installed at the Southwick Power Station of Brighton Corporation Electricity Undertaking. They have a reactance of 15 per cent. on 30,000 kVA., 8 kV., 3 phase, 50 cycles.

At the Southwick Power Station of the Brighton Corporation Electricity Undertaking the generator busbar pressure is 8 kV. The busbar is arranged so that it can be separated into two sections; to one section 30,000 kW. and 15,000 kW. generators are connected, and on the other section there are 30,000 kW., 15,625 kW. and 6,000 kW. generators; also, coupled to each section is a C.E.B. supply which is given from the 132 kV. Grid through a double transformation, viz., 132/33 kV. and 33/8 kV. The two sections of the busbar are coupled through a reactor, designed to operate continuously with the maximum transfer of power of 30,000 kVA, and having a reactance of fifteen per cent., which value is necessary to limit the short-circuit current under the worst conditions to the safe rupturing capacity of the switchgear, viz., 750,000 kVA.

The reactor comprises a bank of three single-phase units, which are of the oil-immersed type and are installed out of doors. The maximum

continuous current is 2,165 amperes, and the coil is wound with an enamelled stranded cable in two parallel sections : the winding is designed to withstand the short-circuit current of 14,450 amperes for 5 seconds. The interturn insulation and spacing is similar to that described on page 143 and illustrated in Fig. 2. The influence of the flux of the coil is controlled by a magnetic shield which is built on the principle of a three-limb single-phase transformer where the windings are on the centre limb, except, of course, that with reactors there is no steel in this limb. This design provides adequate shielding and the reactance characteristic is practically a straight line. The total loss at normal current is 22.5 kW. at 75 deg. C. for each single-phase unit.

The bank of reactors is illustrated in Fig. 1. The tanks are of the tubular type, sufficient cooling surface being provided in an efficient manner with elliptical tube bent on edge, and an explosion diaphragm and expansion vessel are supplied ; in the oil pipe between the main tank and the expansion vessel is mounted a Buchholz protective device. Electrical connection to the reactors is made through three single-core lead-covered cables per phase ; the cable boxes are made of silica-aluminium and are amply proportioned to facilitate the handling of the heavy cables. The boxes are filled with " Trinidite " O.T.R., an oil-resisting compound, and connection to the main tank is made through porcelain insulators fixed horizontally in a barrier between the cable box and the disconnecting chamber mounted on the main tank cover ; the oil in this chamber is common to the oil in the main tank, and it is necessary to withdraw only a few gallons of oil to gain access to the links in the disconnecting chamber. The tank is supported on a skid type underbase. The weight of a single-phase unit complete with oil is 6½ tons.

Some of the power generated at the Southwick Power Station is distributed at 8 kV. to the Hove and Shoreham Undertakings, but the supply to Brighton is stepped up to 11 kV. by means of auto-transformers and is fed to the North Road Distribution Centre which is located in the heart of the town five miles away. From this substation there is a considerable amount of distribution by means of D.C., rotary converting plant being used. Originally the supply to this plant was at 8 kV. from the Power Station, but, as stated above, 11 kV. supply is now available, and step-down auto-transformers are installed at the substation. The converting plant is controlled by two separate switchboards, each supplied by two transformers. Board " B " controls three 1,000 kW. and one 1,500 kW. motor converters and two 1,500 kW. synchronous motor generators and one 300 kW-set., and the supply is through two 11,000 kVA. auto-transformers. Board " C " controls two 1,500 kW. rotary converters and five 500 kW. induction motor generators, the supply being through two 6,000 kVA. auto-transformers.

In order to restrict the maximum short-circuit kVA. to a value that can be dealt with safely by the existing switchgear the necessary reactance is provided in the transformers, the value for the 11,000 kVA. units being 11 per cent. and that for the 6,000 kVA. units being 6 per cent. The transformers are of the three-phase core type ; the windings of the 11,000 kVA units are arranged in a sandwich manner to secure the high reactance, but for the 6,000 kVA. units the windings are arranged concentrically. The efficiency at full load and unity power factor and at 75 deg. C. is 99.51 per cent. and 99.53 per cent. for the 11,000 kVA. and 6,000 kVA. transformers respectively. The tanks are half-round ended and cooling surface is provided by elliptical tube bent on edge and welded into the tank side. Cable boxes for three-core cables are mounted on disconnecting chambers fixed on the tank cover, the general arrangement being similar to that described above for the reactors. Expansion vessels and Buchholz protective devices are supplied. The complete transformer substation is shown in Fig. 2.

As will be seen from the illustration, this substation is in close proximity to dwelling houses, and an interesting feature of the installation is the fire-protection equipment, which is of the " Mulsifyre " type manufactured by Messrs. Mather & Platt, Ltd. The principle of the scheme is that if the surface of the oil is emulsified it cannot burn. The emulsification of the

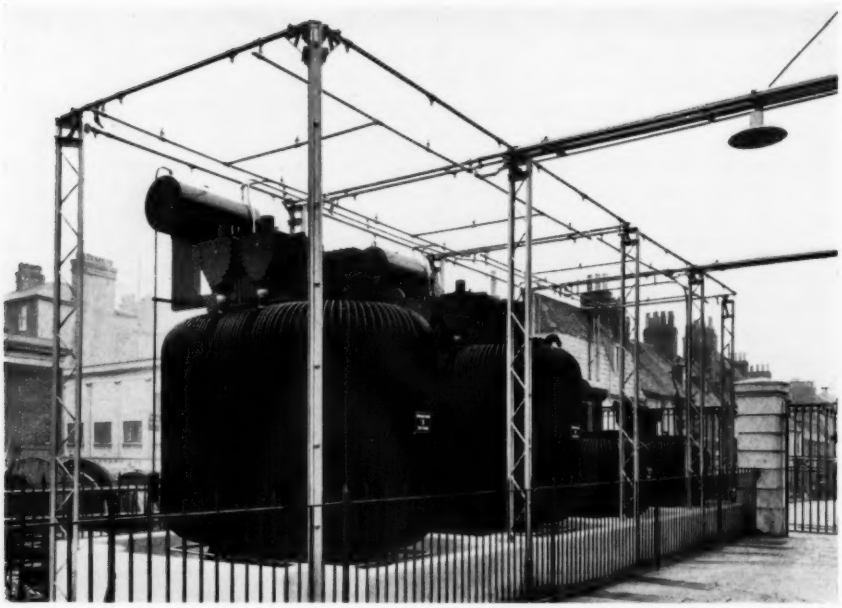


Fig. 2. The North Road Distribution Centre of Brighton Corporation Electricity Undertaking, showing 11,000 kVA. and 6,000 kVA. Transformers, together with the "Mulsifyre" fire-protection equipment.

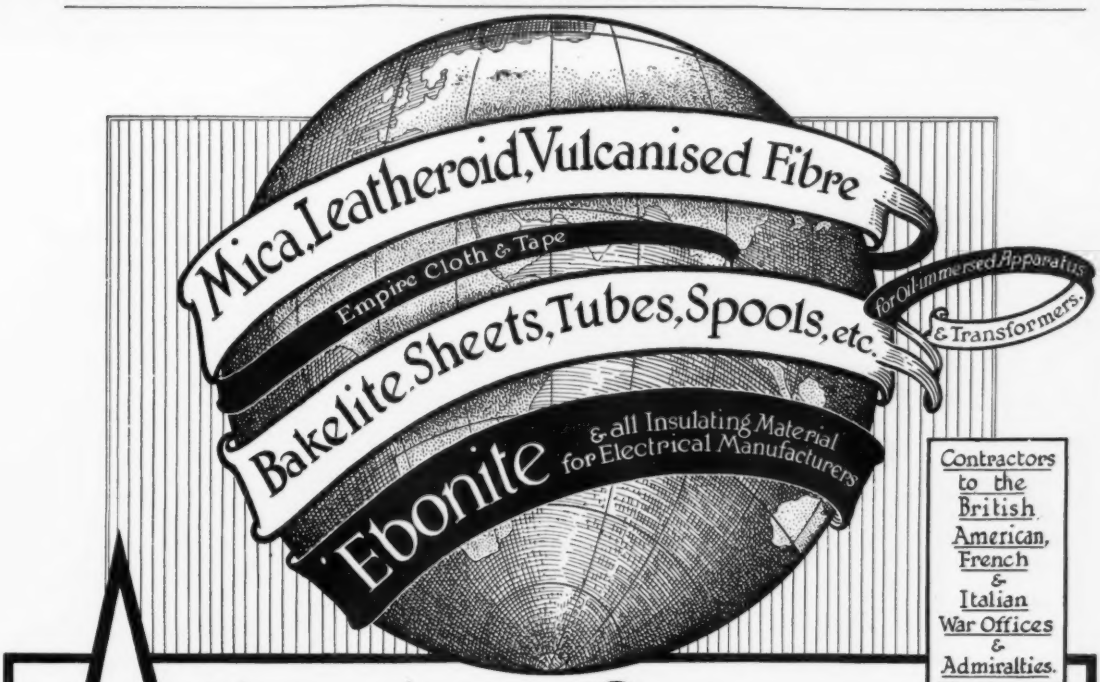
oil is produced by discharging water through projectors, which cause a spray to impinge with considerable force on to, and well distributed over, the surface of the oil. Only a thin film at the surface needs to be emulsified, and this is achieved almost instantaneously, with the result that the fire is extinguished within a few seconds of the time the water is turned on.

Fig. 2 shows the water system and the projectors pointing downwards. Another system of smaller piping, with pilot sprinkler fittings pointing upwards, can be seen in the illustration. This system is filled with air under pressure, and is connected to automatic hydraulic valves. Immediately a pilot sprinkler is made to function by a fire, due to a quartz bulb bursting, the pressure in the pipe falls, the hydraulic valve operates and the water is automatically turned on to the projector system. A water pressure of about 40 lbs. per square inch is required at the projector, and if the town supply will not meet this requirement, a pressure tank with a pump is supplied. Such a tank and pump equipment is installed at the North Road Distribution Centre. The air lines containing the fire detectors are pumped up separately to about 20 lbs. per square inch.

In addition to the system mounted above the transformers, there is a ring round each tank underneath the cooling tubes with projectors pointing upwards.

Round each transformer is built a low wall to retain oil that may leak from the tanks in the event of fire, and from each cubicle there is a restricted outlet into a large trench filled with granite chips which empties into the town sewer via an intercepter. The cable trenches are filled with granite chips and have an adequate partition where the cables pass into the sub-station building.

Similar fire protection equipment is being provided for the reactor installation at the Southwick Power Station.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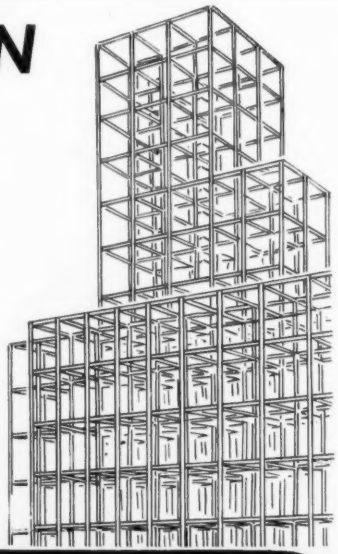

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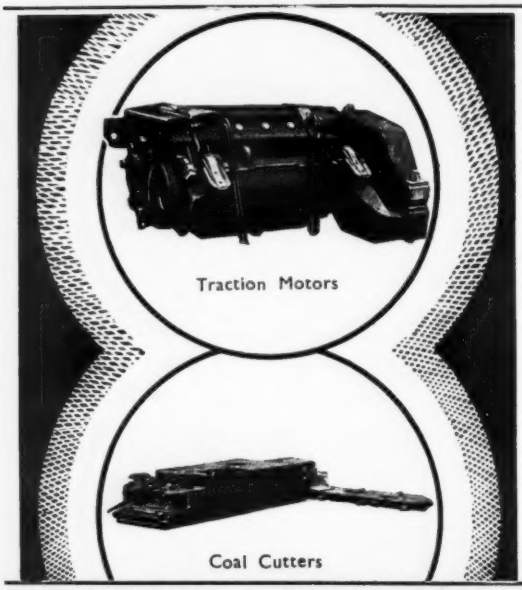

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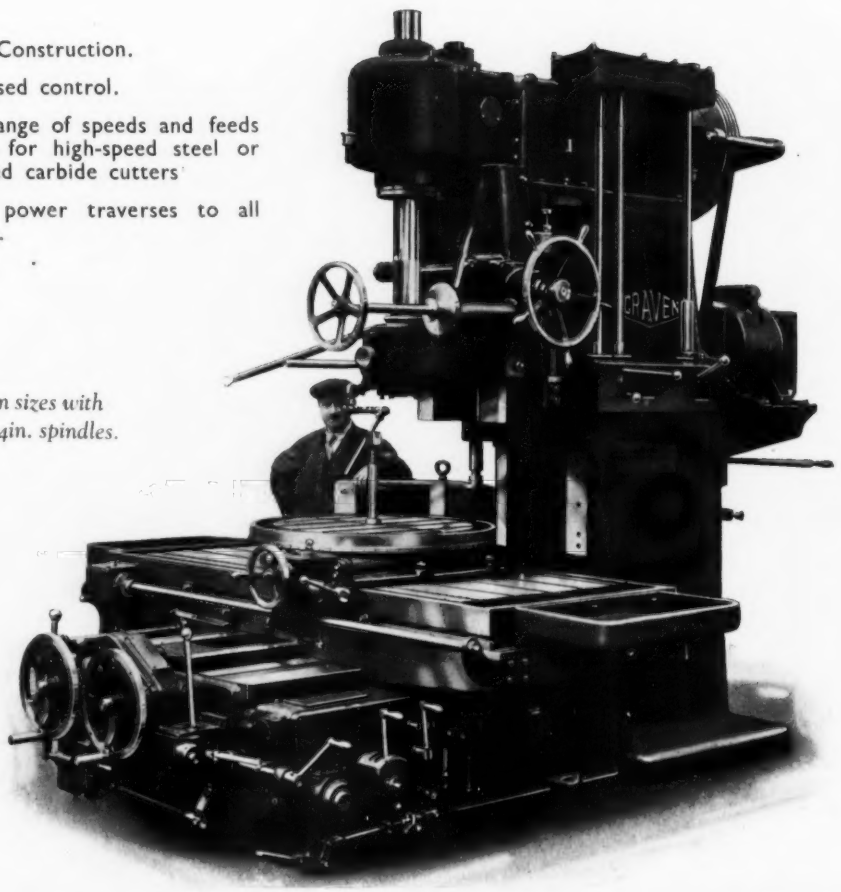

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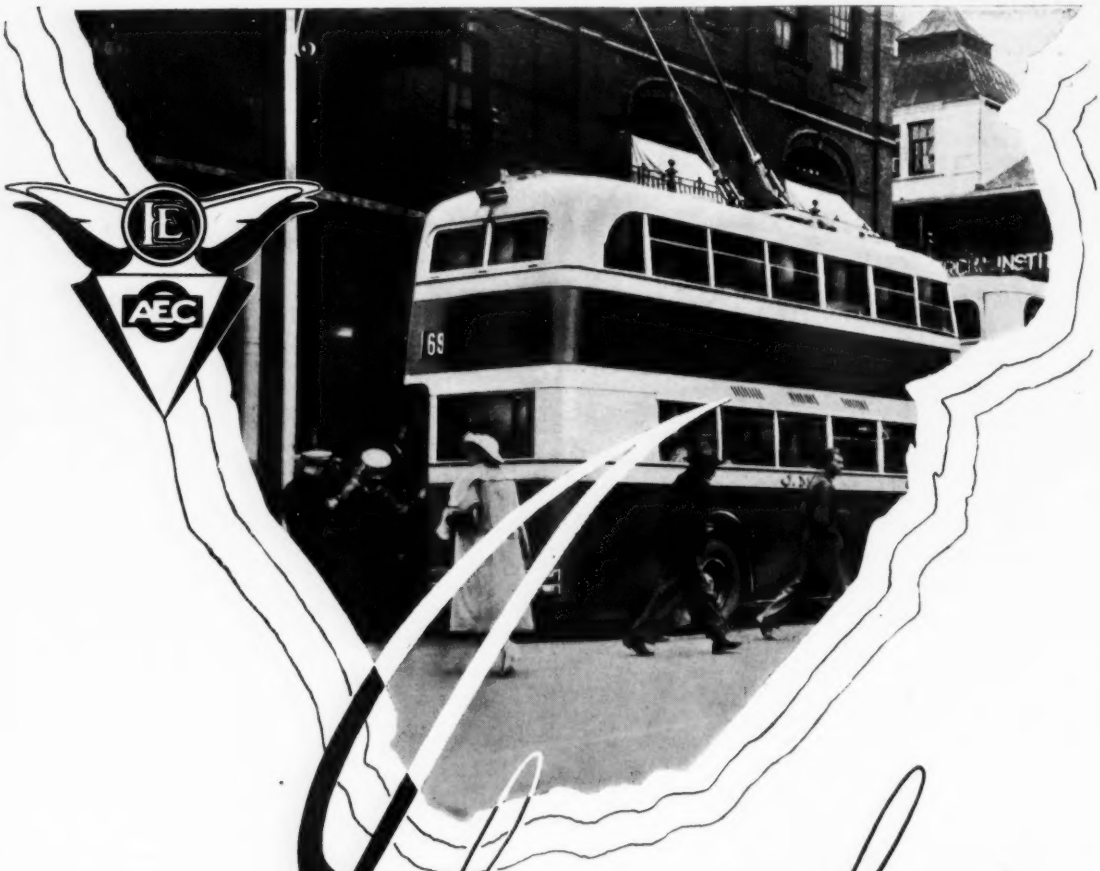

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In addition to the box body type illustrated, machines of round column type can be supplied having circular elevating table arranged to swing aside.

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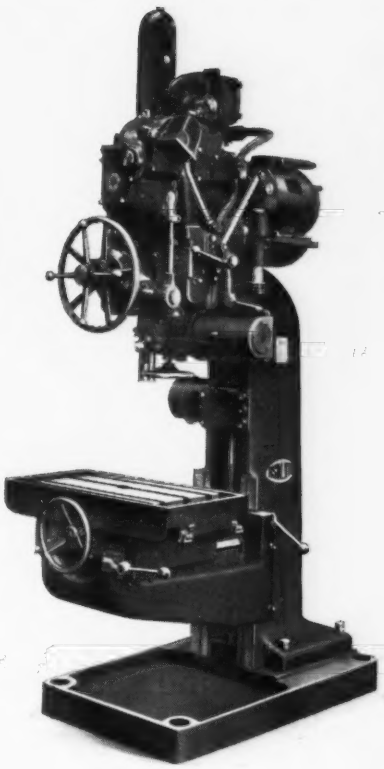

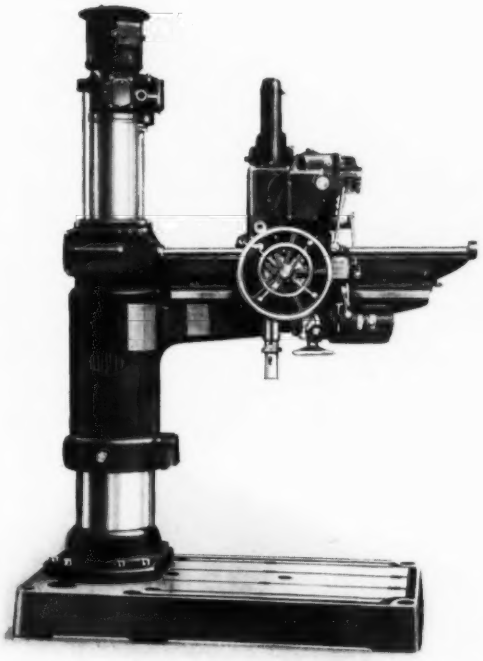

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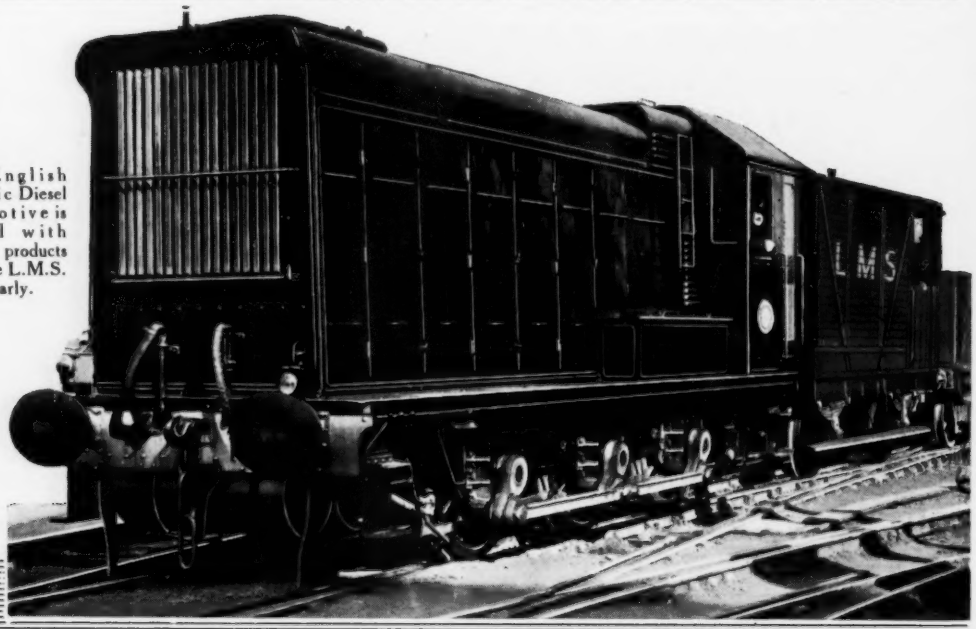

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